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APPLIED MECHANICS REVIEWS

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STRESS ANALYSIS IN THE PRESENCE OF CREEP

I FINNIE

SHELL DEVELOPMENT COMPANY, EMERYVILLE, CALIFORNIA

In many engineering applications the design of parts and the choice of a material must be based wholly or partially on creep behavior. Although the present review is based only on the stress analysis aspects of design for creep, it must be remembered that other factors such as alternating stresses, structural changes in the material during service, or corrosion reactions may not only be of importance in themselves but also may modify creep behavior.

The vast majority of the available creep data have been obtained from constant load uniaxial tension tests. The curve for a typical test of this type, which is often not continued to rupture, is shown in Fig. 1. It should be noted that the secondary stage (minimum creep rate region) may often be very prolonged. The distinction between constant load and constant stress tests is normally only significant in the region of tertiary creep where the decrease of cross section at large strains is largely responsible for the increasing creep rate in constant load tests. In the present discussion, it will be assumed that tension creep data, such as shown in Fig. 1, are available for the temperature and stresses of interest and, if necessary, have been extrapolated to the required time duration.

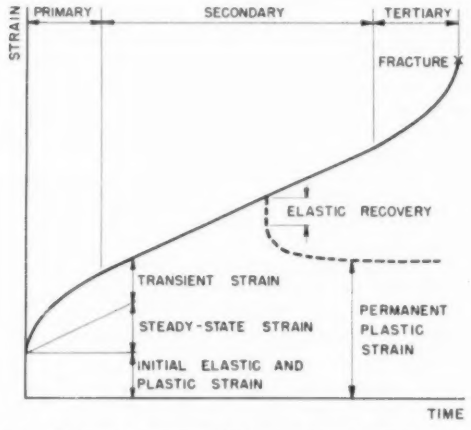

Fig. 1. Schematic constant load creep test. Dotted line shows behavior if specimen is unloaded during test.

In applying tension data to predict creep behavior under varying and combined stresses, it is possible to use the experimental data in numerical form but very often it is more convenient to fit empirical expressions to the data. An obvious point in this connection is that a more elaborate empirical relation will give a more accurate fit to the data and enables a more accurate stress analysis than a simple expression but requires more detailed tensile creep data and will lead to more complex calculations. Since minor changes in stress, temperature, material composition, heat treatment, or method of manufacture may greatly influence creep behavior, the accuracy of a creep calculation must be expected to be considerably less than one for say elastic conditions, and hence a simple approximate empirical representation may be adequate for rational design. In this same spirit, the elastic strain and initial plastic strain are often neglected if they are small relative to creep strain. However, this cannot be done if stress relaxation from an initial elastic state is to be computed.

The simplest empirical representation, and that used to solve many practical problems, is obtained by considering only the steady creep portion of the curve. The strain rate at constant temperature is then only a function of stress, $\dot{\varepsilon} = f(\sigma)$. In many cases this is a reasonable assumption and indeed for a number of materials steady creep data are all that can be obtained from the literature. The functional form most often used is

$$\dot{\varepsilon} = B\sigma^n \qquad [1]$$

where B and n are constants for a given temperature. Other relationships have been employed such as $\dot{\varepsilon} = C \sinh \sigma/d$ and $\dot{\varepsilon} = D e^{\sigma/s}$, where again C, D, d, and s are constants which may depend on temperature.

When the creep curves cannot be idealized as steady creep, the subsequent stress analysis becomes more complicated. However, even in this more general case the stress analysis is simplified by noting that the creep curves for various stresses usually have an approximate geometric similarity which enables the creep strain rate to be written as $\dot{\varepsilon} = F(\sigma)G(t)$. A particular relation sometimes used for the early stage of creep is $\varepsilon = B\sigma^n t^m$, where m usually lies between 0.3 and 0.5. Despite the simplification shown by these equations, the determination of a specific empirical relationship from creep tests is a nontrivial problem, particularly when short time tests are involved. An elegant treatment of this topic has been given by de Lacombe (1).

A previous AMR feature article by F. K. G. Odqvist in December 1954 reviewed the various phenomenological theories of creep. One topic, in particular, for which reference should be made to this article is the representation of primary creep by an equivalent initial strain.

STEADY CREEP UNDER UNIAXIAL STRESS

For situations in which two of the principal stresses are zero, a number of simple but useful solutions may be obtained by combining Eq. [1] with the requirements of force equilibrium and strain compatibility. The extent to which these solutions are in error will depend on the magnitude of the neglected transient creep.

For example, for the relaxation of bolting, the steady-creep solution predicts too high a stress at a given time and the agreement with experiment may be quite poor (2,3). Marin and co-workers have suggested two methods of improving the prediction (4,5). One treats transient creep as an initial effect and makes it possible to obtain a lower limit for the residual stress as a function of time. The other, which is not as easy to use, assumes that transient creep is fully recoverable. Other problems in one strain variable for which steady creep solutions have been obtained, in some cases including transient creep as discussed above, are bending (3,6–10), piping expansion loops (3,10), torsion (3,11), and column buckling (3,12–20).

STEADY CREEP UNDER MULTIAXIAL STRESS

Since the relationship between stress and creep rate is generally nonlinear, it is not possible to solve problems by the superposition of separate solutions. This nonlinearity, while rendering an analysis more complicated than one for elastic conditions, also gives rise to some interesting aspects. As an example, it is found that a tube, subjected to bending moments, will bend more rapidly when internal pressure is also applied (3).

General equations may be derived which predict the creep rates $\dot{\varepsilon}_1$, $\dot{\varepsilon}_2$, $\dot{\varepsilon}_3$, in the directions of the principal stresses σ_1, σ_2, σ_3. Since this derivation has been given many times in the literature (3,22,23,24), it deserves only the barest outline in the present article. Briefly, it is assumed for an isotropic material that (1) creep strain takes place without volumetric deformation, i.e., $\dot{\varepsilon}_1 + \dot{\varepsilon}_2 + \dot{\varepsilon}_3 = 0$, and (2) the principal shear strain rates lie in the same directions and are proportional to the principal shear stresses, i.e.,

$$\frac{\dot{\varepsilon}_1 - \dot{\varepsilon}_2}{\sigma_1 - \sigma_2} = \frac{\dot{\varepsilon}_3 - \dot{\varepsilon}_1}{\sigma_3 - \sigma_1} = \frac{\dot{\varepsilon}_2 - \dot{\varepsilon}_3}{\sigma_2 - \sigma_3} = C \qquad [2]$$

Combining the two equations leads to $\dot{\varepsilon}_1 = \frac{2C}{3}\left[\sigma_1 - \frac{1}{2}(\sigma_2 + \sigma_3)\right]$ and two similar expressions. The two assumptions used in deriving the preceding equations appear to be fairly well confirmed by experiment (23), at least for steady creep.

An additional assumption, also substantiated by experiment (23,25), is that principal stresses and strain rates in steady creep are related by the invariant quantities,

$$\left.\begin{aligned} \sigma^* &= (1/\sqrt{2})\,[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2} \\ \dot{\varepsilon}^* &= (\sqrt{2}/3)\,[(\dot{\varepsilon}_1 - \dot{\varepsilon}_2)^2 + (\dot{\varepsilon}_2 - \dot{\varepsilon}_3)^2 + (\dot{\varepsilon}_3 - \dot{\varepsilon}_1)^2]^{1/2} \end{aligned}\right\} \qquad [3]$$

That is, $\dot{\varepsilon}^* = f(\sigma^*)$, which for simple tension reduces to $\dot{\varepsilon} = f(\sigma)$. Choosing the functional form most often found in practice, $f(\sigma) = B\sigma^n$, and combining with the preceding expressions, results in equations which may be used for stress analysis.

$$\dot{\varepsilon}_1 = \frac{\dot{\varepsilon}^*}{\sigma^*}\left[\sigma_1 - \frac{1}{2}(\sigma_2 + \sigma_3)\right] = B\sigma^{*n-1}\left[\sigma_1 - \frac{1}{2}(\sigma_2 + \sigma_3)\right] \qquad [4]$$

An alternative expression of Eq. [4] is $\dot{\varepsilon}_1 = \dot{\varepsilon}^*\,(\partial\sigma^*/\partial\sigma_1)$, which may be interpreted in terms of a plastic potential. Equations [3] and [4] may also be written in terms of a general state of stress, σ_x, σ_y, σ_z, τ_{xy}, τ_{yz}, τ_{zx}. The alternative expression of Eq. [4] then becomes

$$\dot{\varepsilon}_x = \dot{\varepsilon}^*\,(\partial\sigma^*/\partial\sigma_x),\ \gamma_{xy} = \dot{\varepsilon}^*\,(\partial\sigma^*/\partial\tau_{xy}). \qquad [4a]$$

A number of other equations for the prediction of multiaxial creep strains may be found in the literature (8,26,27,28,29). However, the preceding equations, which were first derived by Odqvist (22), lead to relatively simple calculations and give predictions which are usually in satisfactory agreement with experimental data.

An alternative approach, sometimes followed, is to relate stress and strain rate by the maximum shear quantities, i.e., $(\dot{\varepsilon}_1 - \dot{\varepsilon}_3) = f(\sigma_1 - \sigma_3)$. The logical flow rule to use in this case would be $\dot{\varepsilon}_1 = -\dot{\varepsilon}_3$, $\dot{\varepsilon}_2 = 0$. However, the flow rule of Eq. [2] is often used with the maximum shear relation between stress and strain. This leads to expressions of the form $\dot{\varepsilon}_1 = (3/2)\,B(\sigma_1 - \sigma_3)^{n-1}\,[\sigma_1 - (1/2)\,(\sigma_2 + \sigma_3)]$, which may be easier to use than Eq. [4] if the relative magnitude of the principal stresses is known in advance and does not change during deformation. These equations may be quite adequate for practical prediction although experimental evidence (30) generally appears to favor Eq. [4]. Wahl (31) has used both flow rules with the maximum shear relation between stress and strain rate as well as Eq. [4] to study the creep strains in rotating disks. The errors in such calculations which may arise by neglecting transient creep have been discussed in the literature (32,33).

Equation [4] has been applied to solve a wide variety of problems which can only be cataloged here. Thin-walled cylinder under combinations of tension, torsion, and internal pressure (3,23); thin-walled cylinder under internal pressure and bending (3,21); thick-walled cylinder under internal pressure (3,23); thick-walled cylinder with internal pressure and axial load (35); thick-walled cylinder under internal pressure considering finite strain (36); thick-walled spherical shells under internal pressure (3); expansion of a gas bubble in a metal (3); contraction of ice tunnel in a glacier (37); glacial movements (38,39); thin-walled pressure vessel heads under internal pressure, ellipsoidal and other shapes (40); bending of circular plates (40–44); rotating disks of several shapes (22,31,45–48); relaxation of a cylinder on a shaft (49); buckling of sandwich construction shells (50,51,52).

The preceding solutions may be expected to give relatively accurate stress prediction once steady creep is well established. However, the creep strain predicted will always be in error if appreciable transient creep has occurred. Even small errors in stress prediction over a long period of time may lead to considerable error in strain prediction. In the case of buckling, where initial deflections are very important, the steady-creep solutions may considerably overestimate strength.

VARYING STRESS CONDITIONS

While the steady-creep assumption is adequate for many practical calculations, there are also cases for which it will not suffice. For example, in calculating the relaxation of stress due to creep, the initial stage of the creep curve is very important. In addition, there are many alloys which show no significant steady creep in their time, temperature, and stress range of interest.

For problems in which the stresses are constant and statically determinate, there is no difficulty in predicting strain rates for a material with general creep behavior. Assuming that the constant stress tension creep data may be represented by $\varepsilon = \sigma^n G(t)$, one differentiates with respect to time to obtain $\dot{\varepsilon} = \sigma^n G'(t)$ and replaces the constant B of Eq. [4] in any steady-state creep solutions by $G'(t)$.

When the stresses change during creep, as in statically indeterminate situations, the procedure to be followed is not as obvious. This may be illustrated by the case of simple tension. Figure 2 shows experimental curves of creep strain as a function of time for two constant stresses. We now ask:

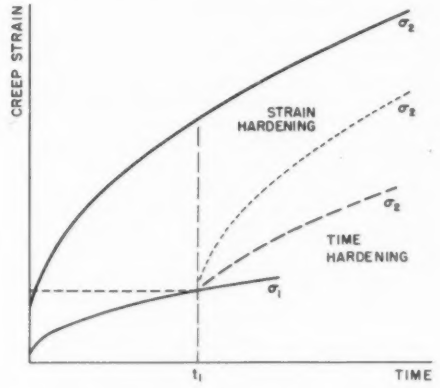

Fig. 2. Creep curves for stresses σ_1 and σ_2, showing also the strain behavior predicted by time hardening and strain hardening theories when the stress is changed from σ_1 to σ_2 at time t_1.

How may these curves be used to predict the creep behavior which will occur if a specimen is subjected to stress σ_1 for time t_1 and then suddenly raised to stress σ_2? Unfortunately, there is no simple answer to this question since the response of the material to stress σ_2 will depend on the structural changes which have taken place in the material during its previous strain history. In addition, these structural changes appear to depend on the path of loading which indicates that the material cannot, in general, be characterized by a unique "equation of state." Although the different individual details of structural change during creep have received a great deal of attention in metallurgical studies, they are still not completely understood. Hence, for the purposes of a mechanical stress analysis, one has to rely on certain simple approximations for the dependence of the creep strain rate on prior events. Although it seems unlikely that any single simple method will apply with accuracy to the wide variety of creeping materials, it is nevertheless necessary to search for approximations which will enable practical estimates for engineering problems.

If the period of prior deformation has been relatively short, it would appear that the creep strain should characterize the changes which have occurred during the history of loading. On the other hand, if the deformation occurs over a long period of time under stresses which do not vary too rapidly, then the time at temperature may provide a better basis for comparison of structural changes in the material. Figure 2 shows the strain behavior predicted by these two methods which are often given the descriptive names *strain hardening* and *time hardening*. Most experimental studies are of relatively short duration, and, as might be expected, tend to favor the *strain-hardening* prediction (3,53,54,55) although this is not always the case (56).

The two methods of strain prediction may be illustrated by assuming that constant stress creep tests at a given temperature are expressed by $\varepsilon = A\sigma^n t^m$. Differentiating directly yields the time-hardening expression $\dot{\varepsilon} = mA\sigma^n t^{m-1}$, while taking the mth root of both sides of the equation before differentiation leads to the strain-hardening expression $\dot{\varepsilon} = m(A\sigma^n \varepsilon^{m-1})^{1/m}$.

When multiaxial stresses are involved, it is usually assumed that stress, strain, and strain rate may be replaced by the invariants of Eq. [3] (57,58). (The strain invariant is merely the strain rate invariant without time differentiation.) This assumption would appear to require further investigating, particularly for cases in which principal stress directions rotate during deformation. However, if the assumption is accepted, Eq. [4] becomes $\dot{\varepsilon}_1 = (mA^{1/m})\ \sigma^{*(n/m)-1}\ \varepsilon^{*(m-1)/m}$ $[\sigma_1 - (1/2)\ (\sigma_2 + \sigma_3)]$ for strain hardening and $\dot{\varepsilon}_1 = mA\sigma^{*n-1}$ $[\sigma_1 - (1/2)\ (\sigma_2 + \sigma_3)]\ t^{m-1}$ for time hardening. By comparing these two expressions it is clear that the former will lead to considerably greater analytical difficulty than the latter.

Methods of prediction which combine time and strain hardening have also been discussed (58) but have found little application since prior test data are needed if a choice is to be made among the many relationships which are possible. Still another approach which has been used assumed that the fraction of the rupture life used up during creep is a criterion of structural change (59).

Creep Recovery and the Superposition Principle

An obvious defect in all the preceding methods is that they do not predict the gradual recovery of creep strain which occurs upon unloading (see Fig. 1) or partial unloading. For this reason, tests made to compare their predictions with experiment are usually made with increasing stress levels, although the case of decreasing stress is very often found in practice. Data on creep recovery are fairly limited, but rather complete information for a carbon steel has been given by Johnson (60).

Attempts have been made to develop expressions for the creep strain which would be general enough to include creep recovery. The basis for this work is the superposition principle of Boltzmann (61) which was an attempt to relate the behavior of a material at a given time to its past history of loading. Originally formulated for materials whose strain behavior is linearly proportional to stress, the principle states that the strain at any time due to a variable load history is given by the sum of the strain contributions from each past instant of time. Each contribution is proportional to the stress at the past instant and is weighted by a function of the time elapsed from that instant (memory function). The development of these theories and their application to fibers and plastics has been given very completely by Leaderman (62) and Alfrey (63), and their mathematical structure has been discussed in considerable detail (e.g., 64,65).

The application of the superposition principle to nonlinear creep behavior has been discussed by Rabotnov (66). He assumed a linear relation between some function of strain and the whole history of stress, weighted by a suitable memory function. This formulation leads to an integral equation which is soluble after further simplification. Applications of this rather general approach to practical problems appear to have been limited by computational difficulties. Other formulations of integral equations for nonlinear creep have been given by Rosovskii (67) and Arutiunian (68,69). This latter worker and colleagues have used this approach to study thin-walled rods with closed cross section under torsion and composite tubes under internal pressure. These solutions, as well as those obtained by Rosovskii for a concrete shell under external pressure (70), are obtained by successive approximations with the linear solution used as an initial estimate.

Another approach to the inclusion of creep recovery in a stress analysis has been made by assuming that transient creep is the recoverable portion (5). While approximately true for plastics, this assumption may greatly overestimate the creep recovery in metals. Although the separation of creep into components such as transient or steady is often made for convenience, it should not be inferred that these components correspond to physically independent strain mechanisms or even to the most precise representation of creep data.

In addition to the tests already cited, various methods of strain prediction have been compared with experiment for bolting relaxation (3,71,72,73), combined stress relaxation (74), rotating disks (32), and varying combinations of biaxial stress (58). Generalization, from the limited test data to the wide range of situations which may arise in practice, is necessarily limited. However, if stresses relax slowly from initial elastic values (e.g., in a rotating disk or in bolting) and change by no more than, say, half of their original values while the principal stress directions remain fixed, then it appears that the simple time-hardening predictions will be adequate for most practical calculations.

On the other hand, tests made by Johnson (58) in which increments of torque were added to a tube already creeping in tension showed that strain hardening, time hardening, the combination of the two, or the superposition theory could all lead to considerable error in predicting the shear strain in the tube. Of all these different approaches, the predictions of the superposition theory generally showed the smallest divergence from experiment. From these tests it appears that, when the principal stress axes rotate, a more general approach to strain rate prediction is required. Before discussing this topic, we turn first to the many useful solutions which have been obtained by using the strain-rate relations already discussed.

TEMPERATURE GRADIENTS

Most creep calculations assume that the stressed member is at a uniform temperature. If there is even a slight temperature gradient, this assumption may no longer be tenable. The creep strain and stress distribution may be altered significantly by the temperature gradient and thermal stresses will be produced. The rate at which these thermal stresses are relieved by creep may also be of interest.

The effect of temperature on creep rate has been discussed by many writers and the dependence usually found is $\dot{\varepsilon} \sim \exp(-C/T^\circ$ absolute). However for the relatively small variation in temperature which occurs across a stressed metal part, it is usually more convenient, and sufficiently accurate, to write $\dot{\varepsilon} \sim \exp(\alpha T^\circ)$, where α is a constant. This assumption enables closed solutions to be obtained for the steady creep stress distribution in a thick-walled cylinder, with radial temperature gradient, under internal pressure (3,75), or under bending load (76). It is worth noting that the magnitude of the heat-transfer parameter $\alpha Q_0 R_0/K$ (where Q_0 is heat flux per unit time per unit outside tube area, R_0 is outside tube radius, and K is thermal conductivity) may greatly influence the stress distribution. Most of the numerical methods of solution which will be discussed in the next section may be applied to situations in which temperatures vary.

The relief of thermal stress by creep may have interesting consequences. On cooling from the relatively stress-free state produced by creep, the thermal stresses will be opposite in sign to their initial value. Tensile failure of brittle materials designed to withstand compressive stress has been explained in this manner (77). Another effect arises where constrained thermal expansion in a member of varying strength is relieved by creep (78). The majority of the deformation occurs in the weakest section which may become seriously overstrained. This effect may occur, for example, in high-temperature piping systems (10).

General equations for analyzing the effect of creep on thermal stress distributions have been given by Poritsky and Fend (79).

If differential thermal strains are cyclic in nature, then the creep deformation under constant external loads may increase due to the thermal strain cycling (80).

METHODS OF SOLUTION

We turn now to a discussion of the solutions which have been obtained by using the strain rate relations previously discussed. It is convenient to classify these solutions in terms of the material behavior which they assume.

Linear Behavior

The incompressible solid with linear viscosity (i.e., $n = 1$ in Eqs. [1] and [4]) is the simplest creep behavior to analyze. While such linear stress dependence is only rarely found in metals, it is characteristic of many plastics and concrete. The correspondence between this behavior and linear elasticity was pointed out by Rayleigh (81) and has been extended to incompressible viscoelastic materials by Alfrey (82). Thus, many solutions may be obtained directly from existing solutions in the theory of elasticity. Furthermore, Hoff (83) has pointed out that an analogy can also be drawn between nonlinear steady creep and nonlinear elasticity.

The growth in high polymer technology in recent years and an increased interest in the creep of concrete have encouraged the study of materials with time-dependent strains proportional to stress. Using the superposition principle mentioned earlier, and the concept of a spectrum of retardation or relaxation times, it is possible in principle to interrelate creep and relaxation tests or general tests with time-varying stress and even to estimate creep data from internal friction tests at high frequencies (3,63).

The first studies of creep buckling in columns were based on linear relations between creep strain and stress. Since concrete was usually the material of interest, this enabled reasonable predictions of column behavior. The same relations were also applied to metals but failed to predict the catastrophic effects which occur in creep buckling of materials with nonlinear stress dependence.

Steady Creep Behavior

The simplest solutions which begin to represent the behavior of metals are those based on steady-state creep and the basic equations corresponding to this approach have already been discussed. Even for this rather simplified type of material behavior, numerical methods of solution are required for all but the simplest problems (e.g., 35,36).

An interesting approximate solution for the eccentric wall thick cylinder has been obtained by Kachanov (34). He introduces a small parameter λ which linearizes the equation to be solved. The unknown stress function φ which yields the desired stresses is written as $\varphi = \varphi_0 + \lambda\varphi_1$, where φ_0 is the stress function corresponding to the uniform wall cylinder. Then it can be shown that $\sigma^* \approx \sigma_0^* + \lambda\sigma_1^*$. A book (43) by the same author shows other applications of this technique.

Another route to steady-creep solutions lies in the use of variational principles. Methods already developed for nonlinear elasticity may be applied to steady-state creep by invoking the analogy between these two types of behavior. Quantities W and $\overline{W}$ can then be defined by analogy to U, the potential energy, and $\overline{U}$ the complementary energy of elastic theory. If it is assumed that an approximate solution for the strain rates has been found which satisfies the strain-rate boundary conditions and an approximate solution for the stresses has been found which satisfies equilibrium and the force boundary conditions, then approximate quantities W' and $\overline{W}'$ may be calculated. Since $W + \overline{W} = 0$ for the actual solution and $W' \leq W$, $\overline{W} \leq \overline{W}'$, then $-\overline{W}' \leq -\overline{W} = W \leq W'$. In this way upper and lower bounds for the energy functions can be obtained.

Simple examples to indicate the use of variational methods have been given a number of times in the literature (3), but their application to hitherto unsolved problems is rare. A case in which the variational methods have been proven particularly helpful has been given by Patel, Venkataraman, and Hodge (11). These workers studied the torsion of prismatic bars in steady creep and showed that the preceding inequali-

ties put bounds on the angular rotation for a given torque. For $n = 3$ (see Eq. [1]), the two bounds differed by only 38 per cent. Such a happy outcome is not always achieved in more complex strain states, when a stress function is not always available (as it is in torsion) and several strain and stress variables must be handled. It may then not be possible to obtain upper and lower bounds on stress or displacement.

More General Creep Behavior

When the steady creep hypothesis is inadequate, the different approaches discussed earlier have been followed. The time-hardening assumption $\dot{\varepsilon} = \sigma^n G(t)$ has been the one most often employed, for simplicity, and indeed if elastic strains are neglected the stresses are just those predicted for steady creep. In practice if it is necessary to consider more general creep behavior, it is usually also worthwhile to include elastic strains, and even initial plastic strains if present.

The variational principles have received less application to this more general type of behavior except in cases where the stress dependence of creep is linear (82,84). However, Wang and Prager (85) have shown that principles can be stated for a material exhibiting elasticity, plasticity, and steady creep. These are analogous to those developed for steady creep but not as powerful in that they refer only to states of displacement and stress which vary infinitesimally from an initial reference state. Variational principles based on the Wang and Prager approach have been used to solve certain creep buckling problems (86,87,88). Another use of variational methods in which approximate solutions are obtained for certain problems of nonsteady creep is given by Kachanov (43).

We turn now to discuss solutions in which the equations are formulated directly. For problems which involve only one strain variable and essentially no change of shape due to the loading (e.g., bending but not buckling), the combination of elasticity and nonsteady creep may normally be handled by desk calculator (e.g., 89).

However, when multiaxial stresses and strain rates are involved, the combination of elasticity and a realistic type of creep behavior (e.g., strain hardening) usually leads to excessive complication for manual computation and one or two simplifying assumptions are often made. One approximation is to assume volume constancy during elastic deformation. Since there is no volume change during plastic deformation, this enables one strain variable to be eliminated from the analysis. An example of this approximate approach is the solution obtained by Davis for the relaxation of a cylinder shrunk onto a shaft (49).

Another approach to simplifying the equations, which has been followed by many authors (26,90,91), is to write Eq. [2] in terms of strains rather than strain rates. This avoids the problem of handling both strains and strain rates in the same equations. Any concern about the correct representation of creep strain during periods of varying stress is also avoided. While this procedure has led to a number of useful approximate solutions, it is subject to the same criticism as the total strain theories of plasticity.

The more exact treatment which considers both strains and strain rates has not often been employed. Poritsky and Fend (79) have calculated the relaxation of thermal stress in a material which shows elasticity and a strain-hardening type of creep behavior. The equations are arranged for approximate solution by desk calculator. The same type of material behavior, and also time-hardening creep expressions, were considered by Mendelsohn, et al (32) who programmed the equations for digital computer solution. Thermal stresses and initial plastic strains may readily be considered in this formulation.

Iso-curves and Buckling

The approximate approach in which strains are written rather than strain rates leads naturally to the concept, due originally to McVetty (92), of the iso-curves, or iso-chronous stress-strain curves. These are obtained by replotting constant stress (or load) creep test data as fictitious stress-strain curves for a given time. The "iso-curves" are used with the methods of ordinary plasticity to predict the stress distribution at a given time. However, as pointed out by Shanley (20), the iso-curve overestimates the strain in a region where stress has been increasing and underestimates the strain for decreasing stress.

The iso-curve approach has been used extensively in studies of column buckling and in effect replaces an exact creep buckling calculation by one for an eccentric inelastic column, which would be expected to be more conservative (93). Since this latter calculation is in itself fairly time consuming, the tangent to the iso-curve is sometimes used in a similar manner to the tangent-modulus equation of inelastic column theory. This approximation to a conservative estimate may or may not be conservative (94).

There is a large amount of literature on the creep buckling columns but, as many of the solutions have already been discussed in review articles (14,51,95), there will be no attempt here to give complete coverage. From the practical point of view, a problem is that the idealizations of the creep curve, which give reasonable predictions of, say, the long time deflections of a beam under constant bending moments, may be quite inadequate for column buckling predictions. Initial eccentricity of shape and deflections during the initial stage of creep may have a dominant influence on buckling behavior. With this in mind, there have been a number of "complete" analyses of column behavior, some of which require computer solutions (96–99). For members other than columns, the creep buckling literature is not as plentiful. Solutions, based on steady creep, have been given for the buckling of sandwich construction shells, in which concentric cylindrical shells carry normal loads and the annular core carries shear loads (50,51,52). In addition, approximate solutions, of uncertain accuracy, have been obtained by substituting the appropriate time-dependent "moduli" into inelastic buckling solutions.

An interesting approximate approach to the creep buckling of frameworks has been given by Hult (100) who used the concept of creep "hinges" at which all the deformation concentrates.

MORE GENERAL REPRESENTATION OF CREEP BEHAVIOR

Even the most elaborate of the methods of solution which have been discussed makes use of relatively simple empirical expressions for the creep rates. Although this may be adequate for most practical applications, it may be worthwhile to consider some of the more general relationships which are possible.

The most general form of the multiaxial stress-strain relation for an isotropic, incompressible material in which the directions and magnitudes of the principal stresses are fixed, but Eq. [2] is not necessarily satisfied, has been given by Prager (101) and Reiner (102). Applying their arguments to steady creep for which the strain rates are a function only of the stresses leads to expressions for the principal strain rates of the form $\dot{\varepsilon}_1 = f(J_2, J_3)[p(J_2, J_3)\, J_3\, T_1 + g(J_2, J_3)\, S_1]$. Here $J_2 = (1/2)(S_1^2 + S_2^2 + S_3^2) = 1/3(\sigma^*)^2$, $J_3 = (1/3)(S_1^3 + S_2^3 + S_3^3)$, where $S_1 = \sigma_1 - (1/3)(\sigma_1 + \sigma_2 + \sigma_3)$, $T_1 = S_1^2 - (2/3) J_2$, and g is a homogeneous polynomial in the stress components of degree just 4 higher than p which is also a homogeneous polynomial; if p vanishes this condition does not hold. For example, Eq. [4] corresponds to the case $p = 0$, $g =$ constant, and $f =$ (constant) $J_2^{(n-1)/2}$.

The Prager-Reiner equation suggests a large number of stress-strain-rate relations. The task of comparing these with experiment or with Eq. [4] is simplified by using the approach first suggested for plastic flow by Lode (103). The quantity $\mu = [2\sigma_3 - (\sigma_1 + \sigma_2)]/(\sigma_1 - \sigma_2)$ is plotted against $\nu = [2\dot{\varepsilon}_3 - (\dot{\varepsilon}_1 + \dot{\varepsilon}_2)]/(\dot{\varepsilon}_1 - \dot{\varepsilon}_2)$. Equation [4] plots as the straight line $\mu = \nu$ and deviation of experimental data from this relationship indicates that a more general expression is required. Note that elastic strains must be small for this approach to be meaningful.

One example of a more general relation than Eq. [2] is that used by Bailey in his 1935 paper (8) which was a pioneer in the field of creep stress analysis. Bailey's original formulation was $\dot{\varepsilon}_1 = c\sigma^{*2m}[(\sigma_1 - \sigma_2)^{n-2m} - (\sigma_3 - \sigma_1)^{n-2m}]$ and is only valid in that form if $n - 2m$ is an odd integer. For example, if $(n - 2m) = 3$, the Bailey expression becomes $\dot{\varepsilon}_1 = c J_2^{(m+1)} S_1$, using the present notation. The Bailey equation with its two disposable constants can naturally be made to give a closer fit to experimental data than Eq. [4]. However, it is rarely used in practice since it predicts nearly the same strain rates as Eq. [4] and is harder to manipulate.

It should be mentioned that the simple power law relation between stress and strain rate invariants may sometimes be inadequate. A relationship used by Johnson (23) ($\dot{\varepsilon}^* = c_1\sigma^{*p_1} + c_2\sigma^{*p_2}$) is particularly useful, when the creep rate shows greatly different stress dependence for high and low stresses, and does not greatly complicate the analysis.

Johnson (23) has also discussed the development of anisotropy in tests made on tubes under constant levels of combined tension-torsion. He found that in many cases, under high stresses, the strain rates at a given time were given by $\dot{\varepsilon}_1 = F(\sigma^*)[(\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)]$; $\dot{\varepsilon}_2 = F(\sigma^*)[C(\sigma_2 - \sigma_3) - (\sigma_1 - \sigma_2)]$; $\dot{\varepsilon}_3 = F(\sigma^*)[(\sigma_3 - \sigma_1) - C(\sigma_3 - \sigma_2)]$. C is a constant for a given stress system but varies from system to system. A more general type of anisotropy in which the shear stresses appear as $C(\sigma_1 - \sigma_2)$, $D(\sigma_2 - \sigma_3)$, and $E(\sigma_3 - \sigma_1)$ was observed in other tests. The theoretical treatment of materials which possess initial anisotropy, developed for yield and plastic flow by Hill (104), may, presumably, also be applied to steady creep. For orthotropic incompressible materials, he assumed the existence of the quantity $\sigma^* = (1/\sqrt{2})[C(\sigma_x - \sigma_y)^2 + D(\sigma_y - \sigma_z)^2 + E(\sigma_z - \sigma_x)^2 + 2L\tau_{yz}^2 + 2M\tau_{zx}^2 + 2N\tau_{xy}^2]^{1/2}$. Since the axes are now specified by the material, it is not in general helpful to refer to the principal stress directions. However, if these coincide with the axes of anisotropy, the shear stress terms vanish. Applying the relations $\dot{\varepsilon}_x = (\partial\sigma^*/\partial\sigma_x)\dot{\varepsilon}^*$, $\dot{\gamma}_{xy} = (\partial\sigma^*/\partial\tau_{xy})\dot{\varepsilon}^*$ of Eq. [4a] leads to $\dot{\varepsilon}_x = F(\sigma^*)[C(\sigma_x - \sigma_y) - E(\sigma_z - \sigma_x)]$; $\dot{\gamma}_{xy} = 2F(\sigma^*)N\tau_{xy}$, etc. Presumably this derivation is readily extended to time-varying strain under constant stresses but its application to generalize a strain-hardening-type expression for varying stresses is less clear cut.

Hu (105) has defined a parameter μ' for anistropic plasticity which is analogous to the Lode variable μ for the isotropic case. This enables the validity of the generalized invariant σ^* to be studied. Such tests have apparently not been carried out yet for creep deformations.

For situations other than steady creep, it must be admitted that relatively little experimental information is available to guide a choice of strain-rate relationships. The principal work in this field is that of Johnson (58). Finding all of the present mechanical theories unreliable for predicting the shear strain produced by adding torque to a tube already creeping in tension, he has proposed a more general representation of creep data which still assumes Eq. [2] and the condition of volume constancy. This has the form $\dot{\varepsilon}_1 = [f(J_2) - g(I_2)]S_1 F(t)$, where I_2 is the integrated invariant creep strain during previous loading and $F(t)$ is the time dependence of the virgin material. On this basis, the tests described give very good agreement with experiment.

Another aspect to be considered in comparing prediction with experiment is the presence of finite strains and strain rates. While not always a problem in practical situations, there are occasions, such as in short-time rupture tests, when strains may be large. Rimrott (36) has studied the steady creep of a thick-walled tube under internal pressure when the strains are finite. In this situation the formulation of the equations in terms of natural (logarithmic) strain is quite straightforward although their solution is time consuming. In more complex situations, where the principal strain directions rotate and a more general creep behavior is assumed, the difficulties of formulation will be considerable.

TERTIARY CREEP AND RUPTURE

The conditions governing stress rupture in metals under constant multiaxial stress have received considerable attention in recent years. It has become apparent that, while creep deformation is controlled by the magnitude of the invariant quantity σ^*, the rupture life is more closely related to the maximum tensile stress (30,106,107). In the past, before this information was available, it was sometimes assumed that the rupture life would be governed by σ^*. This reasoning persists in certain codes, and it should be noted that it leads to overoptimistic rupture life prediction for thin-walled tubes or vessels under internal pressure. If fracture is accompanied by large deformations or if loads or temperature change during the life of the part, then the conditions governing rupture are not at all clear. The straightforward "cumulative rupture life" concept due to Robinson (108) assumes that rupture occurs when the sum of the fractions (time at a given stress and temperature/rupture life at that stress and temperature) reaches unity. This is adequate in many situations, but its limitations are not well established.

When creep takes place under constant loads, the increasing stress due to decreasing specimen dimensions is largely responsible for accelerating creep rate during tertiary creep. For situations in which the ductility to fracture of the material is very large, it is thus possible to estimate the life of the structure from creep considerations alone (48,109,110,111).

The prediction of the stresses in a member approaching rupture at other than very small strains has received little attention. Anisotropy may very likely develop, in which case the flow law (Eq. [2]) will not apply and in any event the condition of volume constancy is not likely to hold.

CONCLUSION

Many different methods with greatly varying complexity have been used to solve problems of creep stress analysis. On the one hand, if calculations are to be carried out manually, it is often necessary to make greatly simplifying assumptions if the resulting equations are to be at all tractable. On the other hand with the present-day availability of high-speed digital computers, it is possible to solve most of the equations which can be formulated as representative of the physical system. The weakness in these solutions now no longer lies in the simplification of the equations but in uncertainty as to the true physical behavior of materials under time-varying stress. Obviously, solutions offering various amounts of information, in return for complexity, all have their place in engineering analysis.

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102 Reiner, M., A mathematical theory of dilatancy, *Amer. J. Math.* **67**, p. 350, 1945.

103 Lode, W., Der Einfluss der mittleren Hauptspannung auf das Glichen der Metalle, *Forschung. Geb. Ing.* no. 303, 1928.

104 Hill, R., A theory of yielding and plastic flow of anisotropic metals, *Proc. Roy. Soc.*, Lond. (*A*) **193**, p. 281, 1948.

105 Hu, L. W., Studies on plastic flow of anisotropic metals, *J. Appl. Mech.* **23**, p. 444, 1956.

106 Johnson, A. E., and Frost, N. E., Fracture under combined stress creep conditions of a 0.5 per cent molybdenum steel, *Engineer* **191**, p. 434, 1951.

107 Johnson, A. E., Henderson, J., and Mathur, V. D., Combined stress creep fracture of a commercially pure copper at 250 deg. Cent., *Engineer*, **202**, p. 261, 1956.

108 Robinson, E. L., Effect of temperature variation on the long time rupture strength of steels, *ASME Trans.* **74**, p. 777, 1952.

109 Hoff, N. J., Necking and rupture of rods under tensile loads, *J. Appl. Mech.* **20**, p. 105, 1953.

110 Finnie, I., A creep instability of thin walled tubes under internal pressure, *J. Aero. Sci.* **26**, p. 248, 1959; AMR **13**(1960), Rev. 606.

111 Kachanov, L. M., Time of the fracture process under creep conditions (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, p. 26, 1958; AMR **13**(1960), Rev. 1758.

Analytical Methods in Applied Mechanics

(See also Revs. 4987, 5005, 5006, 5013, 5018, 5019, 5036, 5046, 5059, 5061, 5062, 5074, 5083, 5093, 5123, 5215, 5287, 5294, 5358, 5359, 5361, 5447, 5466, 5467, 5475, 5478, 5479, 5485)

4973. Spencer, A. J. M., and Rivlin, R. S., Finite integrity bases for five or fewer symmetric 3 × 3 matrices (in English), *Arch. Rational Mech. Anal.* **2**, 5, 435–446, Feb. 1959.

In a previous paper of Spencer and Rivlin [*Arch. Rational Mech. Anal.* **2**, p. 309, 1958] finite integrity bases for 5 and fewer symmetric 3 × 3 matrices, under the orthogonal transformation group, have been derived. In the present paper it is shown, with the help of some relations derived from the Hamilton-Cayley theorem, that certain of the elements of these integrity bases for 3, 4 and 5 matrices can be expressed as polynomials in the remaining elements.

Edda U. Reeh, Germany

Book—4974. Greenspan, D., Theory and solution of ordinary differential equations, New York, The Macmillan Co., 1960, vii + 148 pp. $5.50.

This elementary text covers first-order equations, linear equations of second and higher orders, existence theorems based on Picard's iteration method and on contraction mappings, Frobenius' method for regular singular points, Sturm-Liouville problems and numerical methods.

Reviewer regrets that the author has chosen to present so much material in a book of less than 150 pages. Students may find parts of the exposition too concise and too demanding. Author omits some proofs, referring the reader to the literature, e.g. Bieberbach's "Theorie der Differentialgleichungen." This may hamper a student whose knowledge of German is scanty. Many exercises are routine, some are marred by misprints.

P. M. Treuenfels, USA

4975. Starzhinskii, V. M., On the stability of a trivial solution of a linear system with periodic coefficients, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 5, 907–921, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author considers a system of ordinary differential equations $dx/dt = A(t)x$, where x is a vector function and $A(t)$ is a periodic matrix function with real, sectionally continuous elements. The trivial solution of the system is $x = 0$. It is known how the stability of the trivial solution depends on the roots of the corresponding characteristic equation. The author investigates and determines the regions of stability and instability in the coefficients of the characteristic equation. He also investigates for stability a certain system of differential equations of the second order, which he is able to reduce to a special case of the first problem. T. Leser, USA

4976. Crandall, S. H., Siebert, W. H., and Hoquetis, B. P., The response of linear systems to non-Gaussian random inputs, *J. Aero/Space Sci.* **27,** 2, 154–155 (Readers' Forum), Feb. 1960.

In most cases filtering favors the Gaussian distribution. Authors show that this is not always true, and as confirmation give examples in which filtering does not favor the Gaussian distribution. V. B. Haas, Jr., USA

4977. Proceedings of the Colloquium on numerical calculations, Perigueux, 1957 (in French), Publ. Scient. Tech. Min. Air, France, Notes Tech. 80, 87 pp., 1959.

Volume contains 7 short notes and 5 longer papers. Principal paper is a detailed exposition by Juricic of fundamental features and techniques of the method of least squares for finding the best parameters of an assumed function representing experimental point data; summarized examples apply the method without much reference to preceding theoretical generalities. Closely related is Arend's contribution on the interpretation of experimental data by linearization of the assumed characteristic function by means of simple coordinate changes. Other practical notes concern a method of summing power series, of finding roots by Lemaitre's "rational iteration," of programming schematically for digital computer the solution of determinants with many zero terms. Theoretical contributions deal with vector and other geometrical point transformations, theorems regarding Hurwitz's and similar determinants. Other short notes are too specialized and incomplete to find place in this review. Reviewer is struck by some of the generalized theoretical treatment, evidently regarded as self-sufficient, in a topic where applicability to concrete problems is all-important, as also by absence of any reference to voluminous recent work in English language. M. L. Meyer, England

4978. Aliab'ev, D. V., A graphical method of determining the statistical mean and mean-square deviations, *Measurement Techniques* no. 3, 282–284, Nov. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 3, 28–30, May/June 1958 by Instrument Society of America, Pittsburgh, 22, Pa.)

4979. Harrison, G., Stationary single-server queuing processes with a finite number of sources, *Operat. Res.* **7,** 4, 458–467, July/Aug. 1959.

Paper examines the finite single-server queue process from a somewhat different point of view than the usual differential-difference equations. The waiting line is considered as a finite Markov chain. $U(i)$ is the number of requests for service when i sources are on the waiting line, and has a distribution function dependent on the service-time distribution and the busy-time distribution. It is shown that $p(i,j)$, the probability that the length of the waiting line is j at a departure, given that at the previous departure the line length was i, is given by

$$\left.\begin{aligned} p(i,j) &= P\{U(i) = j - i + 1\} \\ p(0,j) &= p(1,j) \end{aligned}\right\} \begin{aligned} &i + j = N \\ &i,j = 1,2 \ldots N. \end{aligned}$$

Thus probabilities are defined for transactions between the states defined in the more usual manner. The Markov chain is shown to have a stationary distribution. The method can be applied to distributors other than negative exponential, and an example for constant holding time is given. The treatment is unique and is useful in calculating the expected waiting time for units which arrive when the system is in a particular state, and the transaction probabilities between nonadjacent states.

E. Koenigsberg, USA

4980. Hadley, G. F., How practical is nonlinear programming? —An introduction and some simple practical examples, *Prod. Engng.* **31,** 16, 78–80, Apr. 1960.

4981. Kirkpatrick, E. T., Tables of values of the modified Mathieu functions, *Math. Comput.* **14,** 70, 118–129, Apr. 1960.

Author tabulates the solutions of the first kind of Mathieu's modified equation

$$y'' - (a - 2q\cosh 2u)y = 0 \qquad [1]$$

for characteristic numbers a over the following range of parameters:

$Ce_r(u,q)$: $r = 0(1)5$; $q = 1(1)10(2)20$; $u = .1(.1)1$; 5 D or 5S, mostly

$Se_r(u,q)$: $r = 1(1)6$; same range of q and u as above

Although the tabulation is a sketchy one, it is a welcome contribution to the scant tabular material available. The reviewer spot-checked a few values for $q = 1$ from her more extensive (but unpublished) manuscript of related functions, and found the values correct. Only one misprint was noted: the first reference cited by the author should read N. W. McLachlan (not H. W.)

In applications, one requires not only the solutions $Ce_r(u,q)$ and $Se_r(u,q)$, but also the solutions of [1] of the second kind. Unfortunately the method the author chose for computing the published table cannot be extended for computing the functions of the second kind. The author has not given the important functions $Ce_r(0,q)$, nor does he state where they are available. For the benefit of users, reviewer would like to mention that these can be found in the important tables of the (U. S.) National Bureau of Standards, "Tables relating to Mathieu functions" (1951); they are the values "A", tabulated along with the trigonometric coefficients. The author, in fact, never mentions these tables. Their judicious use would have saved many hours of computing time and might have led to a more flexible (if more sophisticated) program. But one should be grateful for the contribution as it stands.

Gertrude Blanch, USA

Book—4982. Graf, U., and Henning, H. -J., Formulas and tables of mathematical statistics, 2nd revised ed., [Formeln und Tabellen der mathematischen Statistik], Berlin, Springer-Verlag, 1958, vii + 104 pp. DM 12.60.

Whereas the mathematical statistician finds appropriate tables in text- and handbooks of mathematical statistics, the engineer interested in statistics needs a short and concise summary of the most important formulas, tables and nomograms. This is the purpose of the present volume. No derivations or proofs are given. The choice of material is based on engineering applications of statistics, and short examples are given illustrating the use of the most important formulas and tables. Sampling procedures and quality control charts are given particular attention. The present edition differs only slightly from the first (1952) edition, mainly through correction of a few errors.

In all applications of statistics, the user must know enough basic theory to select the appropriate methods correctly and with understanding; thus study of a textbook of statistics must precede

use of this volume of tables. But, given such prior study, reviewer feels this is a very useful and well-written volume, which should be translated into English so as to attract a wider circle of engineers. J. M. Blatt, Australia

Computing Methods and Computers

(See also Revs. 4977, 5012, 5023, 5198, 5231, 5359)

4983. Lowan, A. N., On the propagation of round-off errors in the numerical integration of the heat equation, *Math. Comput.* **14,** 70, 139–146, Apr. 1960.

Upper bounds are given for the round-off error in the numerical solution by finite differences of the one-dimensional heat-conduction equation with prescribed initial and boundary temperature. If the usual explicit difference scheme is used, then the round-off error at the n-th time step, E_n^*, is less than $n10^{-p}$, when the calculations are carried to p decimal places. When the usual implicit difference scheme is used, $E_n^* \leq n\sqrt{M}\delta^*$, where M is the number of interior mesh points, and δ^* is an upper bound for the round-off error introduced in each time step. The value of δ^* depends on the method of solution of the implicit equations, and an expression is derived for it when the solution is by iteration. An expression for δ^* for a direct method of solution is quoted from an AVCO RAD report. H. G. Landau, USA

4984. Hahnemann, H. W., Graphical method to find the real roots of the quadratic, the cubic and the quartic (in German), *Forsch. Geb. Ing. Wes.* **25,** 6, 190–195, 1959.

Method of solution is given for algebraic equations up to the fourth degree by means of slide-rule and graphs for routine engineer use.

The cubic, for example, in its reduced form $y^3 + py + q = 0$ is changed into $z^3/(1 + z) = -p^3/q^2 = K$. The function $K(z)$ needs to be given in a table or graph.

The quartic can be solved by means of the cubic resolvent. As alternative author presents an iteration process of which he states that it does not always converge.

The quartic $x^4 + px^2 + qx + r = 0$ is written as $z^4/(1 + z) = -q^6/r^3 - (pq^2/r^2)z^2/(1 + z) = Q(z) = C - MB(z)$. Iteration starts with C as first approximation of Q. Graphs are needed for $Q(z)$ and $B(z)$. H. J. Schoemaker, Holland

4985. Karibskii, V. V., On the error of a linear interpolator for a program-controlled digital system, *Automation and Remote Control* **20,** 6, 725–732, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 6, 748–755, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The principles of operation of a digital linear interpolator are described, and a theoretical investigation of interpolation error is made. A general expression for this error is derived and an estimate is made of the maximum possible absolute value of this error. From author's summary

Book—4986. Smith, G. W., and Wood, R. C., Principles of analog computation, New York, McGraw-Hill Book Co., Inc., 1959, viii + 234 pp. $7.50.

The literature on analog computers and computation has grown considerably during the past few years. In the books published to date the emphasis has been on design and operational techniques rather than on providing suitable textbooks. The present volume fills this lack to a very great extent. The discussions in it are, however, restricted only to the electronic differential analyzer using the d-c operational amplifier as the basic component.

There are eight chapters each of which has been further divided into several sections. In the first chapter the fundamental components of an analog computer are described and diagramatic representations are given. Elementary techniques by means of which these components are applied in the solution of physical problems are discussed in the second chapter, which is followed by Chapter three dealing with certain standard techniques, particularly block-diagram notation and preparation of Bode plots used for the analysis of linear systems. Chapter four explains how to apply the diode to the simulation of any of the nonlinear phenomenon, and Chapter five gives the application of the relay comparator to the simulation of the same nonlinear phenomenon. In Chapter six the fundamental concept used in all implicit circuits is developed, and application of this concept is then made to obtain circuits which perform the operation of division, square root, arc-sine, and arc-tangent. In Chapter seven description of a few arbitrary function generaters of both curve-following and line-segment types are given. Finally, in Chapter eight the properties of the d-c operational amplifier are considered in detail, and how this device deviates from the ideal is discussed.

Diagrams are used profusely for explaining the principles of analog computation and many worked examples are also given to illustrate the programming of equations requiring several techniques described. Practice problems are given at the end of all applicable chapters. B. M. Belgaumkar, India

4987. El'yasberg, V. M., Investigation of algebraic equations using analog computers, *Automation and Remote Control* **20,** 6, 733–738, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 6, 756–761, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A simple method is presented for the investigation of algebraic equations on analog computers, the method being based on the reproduction of the given polynomial as the solution of the differential equation defining it. The method permits the immediate determination of the real and imaginary roots of algebraic equations, the approximate estimation of the value of their complex roots, and also the investigation of dynamic systems for stability, using the Mikhailov criterion. From author's summary

4988. Kryze, J., A device for solving high-order algebraic equations, *Automation and Remote Control* **20,** 6, 739–748, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 6, 762–772, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Paper describes a high-speed, completely automatic device for simulating algebraic polynomials and solving high-order equations. The device is constructed on a new principle and does not contain electronic vacuum tubes in the simulating (analog) portion, thus removing the basic source of errors. From author's summary

4989. Vol'denberg, Iu. S., A method of solving a particular class of integral equations by casing computers, *Automation and Remote Control* **19,** 8, 712–717, May 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19,** 8, 725–730, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

The Gauss-Seidel method of solving sets of linear algebraic equations, in which the latest available iterated value of each unknown is used at each step, is shown to be readily simulated by electronic-mechanical analogs. The particular analog example employs a cathode ray tube, mechanical scanning disk, and photomultiplier tubes. C. M. Ablow, USA

Analogies

(See also Revs. 4979, 4986, 5022, 5041, 5151, 5208, 5461, 5508)

4990. Noon, W. D., The application of an analog computer to the study of a tractor-trailer suspension system, *G. M. Engng. J.* **7,** 2, 27–31, April–May–June 1960.

4991. Sander, H., An experimental method for the determination of the torsional stiffness of arbitrarily shaped bars of simply connected cross section (in German), *Bauingenieur* **34,** 8, 309–311, Aug. 1959.

Author uses a hydrodynamical analogy established by J. Boussinesq. In the case of pure torsion of a rod the Prandtl stress function is governed by the same relations as the velocities of viscous fluid in laminar flow through a tube of the same cross section. Author used the analogy to determine experimentally the torsional rigidity ratios of rectangular and hexagonal to circular cross section. The results are in good agreement with theoretical solutions. P. Wilde, Poland

4992. Scanlan, R. H., Resistance network solution of some structural problems in deflection and stability, *Proc. Soc. Exp. Stress Anal.* **16,** 1, 117–128, 1958.

Simple linear resistance network is used to solve a class of second- or fourth-order differential equations such as those for bending moments and deflections. Features of the analog permit solution of characteristic value problems. Examples from vibration, column buckling, arch buckling, and lateral buckling of beams are given. W. D. Jordan, USA

4993. Bondar', N. G., The electrical analogy of the oscillations of the static and dynamic rigidities of bar frames (in Russian), Issledovania po teorii sooruzhenii, Moscow, Gosstroiizdat no. 7, 549–574, 1957; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9110.

Author analyzes a number of examples of the possible application of simplest electrical analogs to the problems of natural oscillation and rigidity of bar frame structures treated as systems with a finite number of degrees of freedom. The practicability is indicated of applying the analogy between the problems of static rigidity and of natural oscillation. V. V. Bolotin

Courtesy Referativnyi Zhurnal, USSR

4994. Kunin, I. A., A solution of a certain category of problems by modelling on an electrolytic trough (in Russian), *Izv. Sibirsk. Otd. Akad. Nauk SSSR* no. 7, 53–61, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5951.

In the electric model for the solution of the two-dimensional Poisson equation

$$\nabla^2 \varphi = -\rho(x, y)$$

the right-hand side corresponds to the intensity of the continuously distributed sources of the current. The author gives a description of an apparatus equipped with a trough in which the continuously distributed sources are substituted by concentrated sources in a square network. The satisfactory convergence of the measured and the calculated values for φ is demonstrated in an example. In the case of the generalized equation

$$\nabla(\nu \nabla \varphi) = -\rho$$

the modelling should proceed in the trough with a variable depth proportional to $\nu = \nu(x, y)$. In order to reduce the supplementary sources of error produced in the above procedure the author proposes a linear conversion of the unknown, which ensures a transition to the new equation with smaller variations of ν.

G. Yu. Stepanov

Courtesy Referativnyi Zhurnal, USSR

4995. Prudkovskii, G. P., The use of an electrolytic tank as a computing device, *Instruments and Experimental Techniques* no. 3, 423–426, Apr. 1960. (Translation of *Pribory i Tekhnika Eksperimenta, USSR* no. 3, 77–79, May/June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A description is given of an automatic device which may be used to plot the equipotentials of a harmonic field modelled in an electrolytic tank. The use of the tank as a generator of a given functional dependence is considered.

From author's summary

4996. Bryant, R. A. A., The hydraulic analogy for external flow, *J. Aero/Space Sci.* **27,** 2, 148–149 (Readers' Forum), Feb. 1960.

Author analyzes analogy between one- or two-dimensional hydraulic flow through channels and flow of compressible gases. He finds the one-dimensional hydraulic analogy suitable for "inside," irrotational, isentropic flow. Two-dimensional hydraulic analogies are suitable for "inside" or "outside" flows with vorticity but still isentropic. F. I. Badgley, USA

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 5013, 5018, 5030, 5031, 5093, 5096, 5103, 5465, 5474, 5476, 5479, 5533)

4997. Chzhan,-S.-I., Stability of motion during a finite time interval, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 2, 333–344, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Paper discusses the stability characteristics of physical systems not for infinite time $t \geq t_0$, as is usual, but for a finite interval of time $t_0 \leq t \leq T$. Stability is interpreted in the sense of Lyapunov. The unperturbed motion is said to be stable with respect to given ε and C in the finite time interval if, at $t = t_0$, the solutions $x_s(t)$ of the differential equations of motion satisfy $\sum_s x_s^2(t_0) < \varepsilon$, and if, for all t in the finite interval, $\sum x_s^2(t) \leq C$.

First, linear systems with variable coefficients of the type $dx_s/dt = P_{s1}(t)x_1 + \ldots + p_{sn}(t)x_n$, $(s = 1, \ldots, n)$ are discussed. It is found that the unperturbed motion is stable with respect to ε and C if each of a certain set of n determinants is positive. A special case of a linear system (in which $p_{sr}(t) = c_{sr} + \delta f_{sr}(t)$, δ being small) and a linear system with constant coefficients are then discussed. Nonlinear systems of special types are also discussed.

Throughout, the interest is purely mathematical. No particular systems are treated and no numerical work is reported.

I. N. Sneddon, Scotland

4998. Lur'e, A. I., Equations of perturbed motion in the Kepler problem, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 2, 588–591, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Author uses the method of variation of parameters to derive simple differential equations, of the first order, for the determination of the elements of the orbit of a body moving in the field of a central gravitational mass under perturbing forces. The derivation is both simple and clearly described, but suffers from the fact that there is not a discussion of a specific case.

I. N. Sneddon, Scotland

4999. Ellis, J. W., and McArthur, C. W., Applicability of Euler's dynamical equations to rocket motion, *ARS J.* **29,** 11, 863–864 (Tech. Notes), Nov. 1959.

Using Rosser's statement [Rosser, J. B., et al. "Mathematical theory of rocket flight" McGraw Hill, N. Y., 1947, page 15] authors derive a set of equations for the rotational motion of a rocket with varying moments of inertia and center of mass. Authors note that the additional terms appearing in the generalized Euler equations can be made negligible through design considerations. See also Jarmolow, *J. Appl. Phys.* **28,** 1, 308–313, 1957.

P. Nesbeda, USA

5000. Bentsik, E., About a class of motion of a rigid body loaded with a force of zero potential (in Italian), *R. C. Semin. Mat. Univ. Padova* **29,** 318–327, 1959.

This essay completes Professor G. Grioli's previous work on the same subject [*R. C. Semin. Mat. Univ. Padova* **27,** 1957]. In it author analyzes the kinematic and structural conditions so that the moment of the quantity of movement with respect to the point O of the body may have precessional character: $K_0 = a\bar{H} + b\bar{k}$ [1]; a, b are constants, $\bar{H}$, $\bar{k}$ invariable vectors, fixed, respectively, in space and on the body.

It can be demonstrated that pure rotation must be uniform and, following the principal axis of inertia, coincident with $\bar{H}$ or along a secondary axis, not coincident with $\bar{H}$, so that $b\bar{k} = -(a + 2\sigma)\bar{H}$ where σ is the tensor of inertia. It can also be demonstrated that condition [1] can be satisfied if the body has gyroscopic structure with respect to O, and in this case there are movements of regular precession. For other structural conditions the nonexistence of solutions is verified for hypothesis [1].

F. R. Marsicano, Argentina

5001. Novoselov, V. S., Amplified equations for the motion of nonlinear nonholonomous systems (in Russian), *Uch. Zap. LGU* no. 217, 84–89, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5963.

The author assigns to himself the problem of obtaining equations for the motion of nonholonomous systems which will not only ascertain the spontaneous motion of the system but will also determine the reaction forces of the nonholonomous linkages. For this purpose nonlinear nonholonomous coordinates are introduced in such a way that the formulas for conversion shall contain not only the independent kinematic characteristics l_ν of the system but also, in addition, some independent parameters characterizing the group of linkages. The result was the obtaining, with the aid of N. G. Chetaev's relations, of an extended system of equations for the motions, the number of equations in which was equal to the general number of independents for the kinematic characteristics and the parameter linkages. The author proposes to integrate first of all one group of equations corresponding to the number of kinematic characteristics and then to find, as the result of this step, the natural motion of a system with concrete values for the parameters of the linkages which actually characterize the sought motion. The author considers it possible to find the forces of reaction of the given concrete linkages from the other group of equations.

V. V. Dobronravov

Courtesy Referativnyi Zhurnal, USSR

5002. Novoselov, V. S., Application of the Helmholtz method to the investigation of the motion of nonholonomous systems (in Russian), *Vestn. Leningrad In-ta* no. 1, 80–87, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5964.

An investigation is carried out of the dynamic equations for a motion containing undetermined factors and components in mechanical systems with linear nonholonomous linkages and also with such linkages when nonlinear

$$F_k(\dot{q}_i, q_i, t) = 0 \qquad (i = 1, 2, \ldots, s;\ k = 1, 2, \ldots, r;\ r < s)$$

where possible transpositions of the system satisfy N. G. Chetaev's relations

$$\sum_{i=1}^{s} \frac{\partial F_k}{\partial \dot{q}_i}\,\delta q_i = 0 \qquad (k = 1, 2, \ldots, r)$$

The author indicates a direct method for finding the undetermined Lagrange multipliers and, consequently, of the generalized reaction forces of the linkages in terms of functions of the generalized coordinates, velocities and time. This is followed by a precise generalization of the results obtained by Helmholtz, Meier and Suslov, that is to say: the conditions required in the case under investigation to ensure that every generalized reaction force of the linkages is capable of being presented in a Lagrange form corresponding to the index of some function $U(\dot{q}_i, q_i, t)$; consequently, the system permits the existence of a generalized Helmholtz potential. An algorithm with its working is given for finding a congruent function U. The more concrete of the results obtained are applied to systems with linear nonholonomous linkages, it being assumed that the initial kinetic energy of the system is expressed in normal coordinates; two of the most simple examples are selected for demonstration of similar systems having linkages of a strictly mathematical character.

V. V. Dobronravov

Courtesy Referativnyi Zhurnal, USSR

5003. Egorov, V. B., On Bonnet's theorem, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 6, 1025–1036, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The theorem of Bonnet, well-known in theoretical mechanics, gives the necessary conditions that a mass M acted on by a force $F = \Sigma F_i$ traces a given trajectory ABC when the masses m_i each acted on by a force F_i trace the same trajectory. The author generalizes Bonnet's theorem for the force $F = \Sigma a_i F_i$ (where a_i is a constant). In the second part of his paper, author applies the generalized theorem to the motion of a particle gravitationally attracted by two fixed masses and to the motion of a particle under the action of a central repulsive force inversely proportional to the square of the distance.

The paper ends with a short history of the hyperbolic solution of the last problem.

T. Leser, USA

5004. Himelblau, H., and Keer, L. M., Space requirements for simple mechanical systems excited by random vibration, *J. Acoust. Soc. Amer.* **32,** 1, 76–80, Jan. 1960.

Probability is considered of collision between any of two linear damped mass-spring systems and their base or between themselves when subject to Gaussian white noise at the base. Influence of collisions is neglected.

M. Botman, USA

5005. Caughey, T. K., Response of Van Der Pol's oscillator to random excitation, *ASME Trans.* **81** E (*J. Appl. Mech.*) 3, 345–348, Sept. 1959.

A self-excited Van der Pol oscillator is subjected to white noise excitation. Assuming the noise response to be narrow band Gaussian, and using the method of Rice and Bennett, author computes the periodic and the noise components of the output of the oscillator. The analysis is closely similar to earlier work by Garstens [*J. Appl. Phys.* **28,** p. 353, 1957], but arrives at the opposite conclusion regarding the dependence of the mean-square-noise output on the amplitude of self-oscillation: author finds noise decreases, Garstens finds noise increases, with increasing periodic amplitude. No explanation is given for the discrepancy: an electronic differential analyzer calculation yields numerical results which bear out the present analysis, but reviewer is not satisfied that this problem has been understood from a mathematical point of view.

J. M. Blatt, Australia

5006. Rosenberg, R. M., and Atkinson, C. P., On the natural modes and their stability in nonlinear two-degree-of-freedom systems, *ASME Trans.* **81** E (*J. Appl. Mech.*), 3, 377–385, Sept. 1959.

The natural modes of a symmetrical two-degree-of-freedom system are analyzed theoretically and experimentally. In the presence of nonlinear springs, the two possible periodic solutions (one with the two masses in-phase, the other out-of-phase) are frequently unstable against small perturbations, and thus not realizable physically. A detailed analysis is verified by means of an analog computer. Authors make no reference to the classical theory of stability of motions, based on Hamiltonian dynamics and the Hamilton-Jacobi theory, which is very well-developed in particular

in connection with stability of planetary orbits. Reviewer feels that authors' methods are too special and limited, as a result, although their conclusions are clearly correct for the particular system studied. J. M. Blatt, Australia

Instrumentation and Automatic Control

(See also Revs. 4982, 4985, 4989, 5325, 5411, 5465, 5476)

Book—5007. Lerner, A. Ya., Introduction to and theory of automatic control (in Russian), Moscow, Mashgiz., 1958, 352 pp. + illus. 13r 65k; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6013.

The book consists of three parts. Part I, entitled "Purpose and structure of systems of automatic control," gives a description of the principles of action of systems of control, examples of systems for various purposes, designs for the main components of regulators and methods for deriving the formation of signals of control and assignment. The second part, "Static and dynamic properties of systems of automatic control," gives the static characteristics of the elements and also of the open and closed systems, taking into account types of nonlinearity, the classification of types of linkages in accordance with their dynamic properties, the linear equations and the frequency characteristics of systems of control, the stability of linear systems, calculations for transitional processes in linear systems and a few simple investigations on the processes in nonlinear systems. The third part of the book, "Determination of the structure and calculations for the parameters of systems of automatic control," contains ideas in regard to the selection of types of regulators and their adjustment, the introduction of various linear correcting devices and their synthesis by frequency and root methods and also a description of the principles of construction of quick-action systems capable of reaching optimum limits as regards the time taken for the damping of transitional processes when assisted by nonlinear bonds.

E. P. Popov
Courtesy Referativnyi Zhurnal, USSR

5008. Nadzhafova, G. A., The reproduction of sinusoidal signals by systems with limitations *Automation and Remote Control* **20**, 7, 868–873, Mar. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 7, 892–897, July 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

Considered in this paper are the conditions for partial, and complete, irreproducibility of sinusoidal signals, i.e., the limiting frequency characteristics are determined for standard second-order systems consisting of linear astatic, or static, objects controlled by an astatic servomotor which is limited as to the speed of action and the course of the controlling organ. The amplitude errors of reproduction are determined. From author's summary

5009. Eifert, G., Use of system step response in the selection of control equipment (in German), *Automatisierung: Z. Messen, Steuern, Regeln* **2**, 4, 173–180, Aug. 1959.

Paper describes how step response can be determined experimentally in a pneumatic control system. Techniques are given for determining time constants and transfer functions of first-order and second-order systems from experimental step-response curves. Paper then discusses applications of these parameters to estimate optimum settings for various types of controllers.

T. P. Goodman, USA

5010. Shashkov, A. G., Transient response in a d-c circuit consisting of an ohmic resistance and a thermistor, *Automation and Remote Control* **20**, 1, 20–26, July 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 1, 23–30, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5011. Flidlider, G. M., Transient responses in the magnetic circuits of electromagnetic clutches, *Automation and Remote Control* **20**, 1, 27–40, July 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 1, 31–44, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5012. Basu, S. K., Determination of frequency response from given transient response of a linear system, *J. Sci. Indust. Res., India* **18**B, 4, 137–139, Apr. 1959.

Frequency response is computed from the response to a step function. Sampling operated on the time response at intervals Δt yields steps whose amplitudes respectively are Δf_1, Δf_2 etc., positive or negative. In order to get the response to a sinusoidal input of angular frequency W_k, one adds, vectorwise, all components defined in the following way: the m^{th} has an amplitude equal to Δf_m and a phase equal to $m\omega_k$.

Reviewer believes the idea is new. Industrial application requires that a step input actually be applied.

J. M. Loeb, France

5013. Syui-Yan′, T., and Lui-Vy, T., Auto-oscillations in a single-loop automatic control system containing two symmetric relays, *Automation and Remote Control* **20**, 1, 83–88, July 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 1, 90–94, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The exact equations are derived for the determination of symmetric oscillations. Assuming the linear part of the system to be an ideal filter, author then demonstrates that the exact solution for auto-oscillation frequency agrees with the approximate one derived by the harmonic balance method. The amplitude equations also coincide. Author also infers from the relationships developed that the approximate solution will not agree with the exact one if at least one of the linear filters passes at least one of the higher harmonics produced by the relays. These conclusions can also be extended to single-loop systems containing an arbitrary number of symmetric relays separated by harmonic filters.

R. B. Grant, USA

5014. Meerov, M. V., Synthesis of high-speed automatic control system structures, *Automation and Remote Control* **19**, 7, 611–621, Apr. 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19**, 7, 621–632, July 1958 by Instrument Society of America, Pittsburgh, Pa.)

A system with arbitrarily high gain is shown to be stable if a sufficient number of its elements of second or lower order are placed in appropriate individual feedback loops.

C. M. Ablow, USA

5015. Rozenman, E. A., On the limiting speed of action of servo systems with power, moment and rate limitations on the operating elements, *Automation and Remote Control* **19**, 7, 622–644, Apr. 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19**, 7, 633–655, July 1958 by Instrument Society of America, Pittsburgh, Pa.)

Paper is concerned with a motor whose torque is proportional to current (for example, a d-c motor with constant field excitation). If armature inductance is neglected, motor has second-order differential equation and its motion can be plotted on a phase plane.

It is required to find the necessary variation of current with time such that the time taken for the motor state to change from one point in the phase plane to another is a minimum subject to the conditions: (a) current magnitude, (b) motor speed, (c) motor temperature rise are not to exceed given maximum allowable values. Assumptions made are: (a) heating time constant much greater than

transient time, (b) friction torque much less than inertia torque, (c) initial state is at origin of phase plane.

Using his previous result [*Automation and Remote Control, USSR* **18**, no. 6, 1957] as a basis the author is able to derive the required current variation and the form of the optimum response by variational methods. The phase plane is divided into regions according to the nature of the optimum response for the appropriate limiting conditions. Author states that the results of the paper are easily generalized to include the case where the above assumptions cannot be made. R. J. Kavanagh, England

5016. Starikova, M. V., Study of a sliding regime in an automatic control system (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 12, 53–58, Dec. 1958.

Paper deals with a special control system containing a relay element showing insensitivity and hysteresis. Sliding regime is investigated for which a stable control behavior is generated by permanent vibration on one of the two relay contacts. Due to the vibration, the unsteady characteristics can be replaced by a mean continuous approximation function, which can be computed by harmonic analyses. For the linearized system of equations of this control loop, the transfer function can be computed by approximating the frequency characteristics with a piecewise linear function (trapezoid). K. Magnus, Germany

5017. Sefl, O., Filtering of noise in the optimalizing control (in English), *Scientia Sinica* **7**, 11, 1022–1028, Nov. 1958.

5018. Lehnigk, S., On quadratic forms with parameters as Lyapunov functions (in German), Dtsch. Forschungsanstalt Luftfahrt, Ber. 106, 41 pp., 1958.

In the second method of Lyapunov for determining the stability of certain nonlinear motions, use is made of auxiliary functions often called Lyapunov functions. Making suitable choices for these functions, which must have certain properties of definiteness while at the same time yielding linear estimates of the nonlinearities of the governing system of differential equations, is the chief difficulty in application of this criterion for stability.

Although quadratic forms are usually selected as Lyapunov functions because they satisfy the definiteness requirements, their usefulness is often limited because the linear estimates of the nonlinearities so obtained are valid only within narrow limits.

This paper makes a useful extension of these limits by introducing parameters into the quadratic forms. The method is then applied to a control problem taken from I. Flügge-Lotz [AMR **7**(1954), Rev 3114], and the domains of validity obtained for various values of parameters are compared to those previously obtained for the same problem without the use of parameters.

P. G. Kirmser, USA

5019. Mitsumaki, T., Optimum nonlinear control in retarded systems, *Bull. JSME* **2**, 6, 348–355, May 1959.

Recently, relay control systems have been studied from a new standpoint to obtain an optimum nonlinear control, i.e., utilizing the maximum available power of actuating elements. In this paper, author treats an optimum nonlinear control for the system with a dead time and shows that the optimum performance can be obtained by adding one more switching action to the case for a system without a dead time. If there is no integrating element, it is impossible to obtain an optimum performance with the same switching-curve. However, this defect can be avoided by the use of two controlling elements in parallel.

Author also shows that the switching-curve can be obtained easily by using a transient response.

From author's summary by P. Nesbeda, USA

5020. Tsypkin, Ya. Z., On elimination of the influence of delay on the dynamics of nonlinear sampled-data systems, *Soviet Phys.-Doklady* **4**, 1, 38–42, Aug. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **124**, 4, 812–816, Jan./Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.

Author shows that by the use of a nonlinear discrete filter and an extrapolating device the influence of a finite delay on the dynamic properties of a closed-loop sampled-data control system can be eliminated. The filter consists of delay elements and a number of nonlinear elements; the extrapolating device develops a linear combination of the controlled variable and its derivatives. A schematic diagram of the compensating system is given.

G. D. S. MacLellan, Scotland

5021. Bereza, V. Sh., Statistical evaluation of the accuracy of automatic control of the grinding process in a ball mill, *Automation and Remote Control* **20**, 2, 144–153, Jan. 1960. (Translation of *Avtomatika i Telemekhanika, USSR*, **20**, 2, 150–160, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

It is shown that the powder deviates from its set grain size in a random fashion. The random errors in the grain size are shown to follow a normal distribution law when automatic control is used, and a law with a sharp peak when manual control is used. It is shown that the root-mean-square error can be used as an index to the accuracy of grinding control for a ball mill.

From author's summary

5022. Doganovskii, S. A., and Fel'dbaum, A. A., Analysis of the compensation for strip thickness variations by means of an electronic analog, *Automation and Remote Control* **20**, 2, 185–197, Jan. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20**, 2, 192–205, Feb. 1959 by Instrument Society of America, Pittsburgh, Pa.)

Authors have presented a theory, calculation and an application of analog computer circuit to the compensation of a strip thickness in a simulated three stand rolling mill with a constant strip speed. The tests show that the strip thickness variations at the output were reduced to a fraction of the input value or practically eliminated, thus proving the correctness of their assumptions.

Computers may prove useful in achieving further progress in automation control of the continuous rolling mill process, improvements in the quality of the product and increase in production.

M. Martellotti, USA

5023. Parr, R., and Wordsworth, D. V., Nuclear reactor dynamic analysis, Instn. Mech. Engrs., Prepr., 1958, 12 pp.

Reactor kinetic equations are developed which include the heat-transfer step, following procedures now quite standard. A numerical example is included. The analysis predicts BEPO experimental behavior within 10%. A. Sesonske, USA

5024. Frye, W. E., and Stearns, E. V. B., Stabilization and attitude control of satellite vehicles, *ARS J.* **29**, 12, 927–931, Dec. 1959.

The status of concepts and techniques in the field of satellite attitude control and stabilization as reflected in the open literature of the last five years is reviewed. Stabilization by means of the gravity gradient, aerodynamic torques and radiation pressure is examined. Various attitude sensors and control torque generators are discussed. The sources of disturbing torques are briefly summarized. From authors' summary

5025. Yakushenkov, A. A., Systems of inertial navigation and the prospect for their utilization for sea-going ships (in Russian), *Inform. Sb. Tsentr. N.-i. In-ta Morsk. Flota* no. 14, 3–15, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1138.

A review of articles dealing with the principles, the elements of construction and the defects of inertial systems of navigation. A deduction is drawn regarding the present day lack of precision of

the stabilizing devices which is restricting the application of inertial systems to ship control. The expediency is pointed out of making use of an interim system in which the inertial platform is stabilized by using the stars. A. A. Shpak

Courtesy Referativnyi Zhurnal, USSR

5026. Alimov, Yu. I., The calculation of periodic modes in relay-type automatic control systems, *Automation and Remote Control* **20**, 7, 836–843, Mar. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 7, 860–866, July 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

Exact methods were employed in previous periodic modes in automatic control systems which consisted of relay elements, linear links and inertialess functional transformers which did not appear in supplementary feedback loops and which were not shunted by them.

Examples of the use of this previous method are given. For relay-type systems of extemal control, the results of exact and of approximate calculation are compared.

From author's summary

5027. Chou, C.-L., Investigation of the influence of variations in membrane curvature and effective surface on the operation of pneumatic devices constructed on the principle of force compensation, *Automation and Remote Control* **20**, 6, 749–758, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20**, 6, 773–783, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

An investigation is made of the effect of deviations in effective surface and curvature of rubber-tissue membranes on the quality of operation of pneumatic regulating devices constructed on the principle of force compensation. It is shown that deviations of membranes' effective surfaces from their nominal values can lead to a disruption of regulator adjustment and to the appearance, in isodrome regulators, of residual irregularities.

From author's summary

5028. Grishko, N. V., A peak-holding regulator that follows the peak, *Automation and Remote Control* **20**, 4, 497–499, Jan. 1969. (Translation of *Avtomatika i Telemekhanika, USSR* **20**, 4, 521–524, Apr. 1959, by Instrument Society of America, Pittsburgh 22, Pa.)

A peak-holding regulator that follows the peak is described. It consists of two main parts, one of which measures the distance from the peak, and the other of which is a sampled-data follow-up device. Test results are given; these tests sought to find parameters optimal in the sense that the root-mean-square follow-up error is minimal. From author's summary

5029. Deryugin, V. Kh., A small-size spherical gyropendulum with an electro-dynamic suspension working in conditions stipulating an immovable foundation (in Russian), *Izv. Leningrad Elektrotekhn. In-ta* no. 29, 119–133, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1140.

The known equations for the motion of a single-rotor gyrocompass on an immovable foundation are presented. A description is given of the construction of a gyrocompass with liquid suspension and electromagnetic centering. The procedure is indicated for using the gyroscope for taking underground bearings.

A. A. Shpak

Courtesy Referativnyi Zhurnal, USSR

5030. Pavlov, V. A., The influence on the motion of a gyroscope of a faulty setting of its rotor on the shaft (in Russian), *Trudi Leningrad In-ta Aviats. Priborostr.* no. 24, 15–23, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5985.

An investigation is made of a gyroscope in its cardan suspension. It is assumed that in consequence of faulty assembly the polar axis of the rotor of the gyroscope may prove to be out of alignment with the shaft's axis, forming with the latter a small angle ε. An analysis of the linearized equations of the motion obtained when $\varepsilon \neq 0$ shows that the above defect leads to an oscillatory motion of the system relative to the axis of its suspension. It is indicated the phenomenon of resonance can make its appearance at the determined relationship between the moments of inertia of the rotor and the cardan rings. It should be noted that in the case where the equatorial moment of inertia of the rotor I_e is very large in comparison with the corresponding moments of inertia of the cardan rings, so that it is possible to make $I_c = I_b = I_e$, then the above-mentioned resonance will not occur.

V. N. Koshlyakov

Courtesy Referativnyi Zhurnal, USSR

5031. Zherlakov, A. V., Nondamping oscillations of a double gyroscopic compass (in Russian), *Uch. Zap. Leningrad Vyssh. Inzh.-Morsk. Uch.-shche* no. 3, 20–31, 1956; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5987.

The nondamping motions of the gyrosphere of a double rotor gyrocompass of the "Kurs" type are examined. Most attention is devoted to the investigation of the small motions of the gyrosphere round the North-South line and the motion of the gyroscopes about the axes of their casings. An attempt is made to investigate the problem in a nonlinear setting on the assumption of the finite nature of the angle of swing of the gyroscopes f relative to the axes of precession. An exact formula is put forward for the calculation of the period of oscillation of the gyroscopes inside the gyrosphere. In regard to the analysis of the nonlinear equation [29] for the finite angle f it should be noted that this is arrived at on the assumption of the smallness of the remaining coordinates α, β, γ, for which the author proposes linearization (see p. 23). Consequently the investigation of equation [29] on a phasal plane and by means of application of the "δ-method" is inadequately justified, and right from the beginning the values $\sin f = f$, $\cos f = 1$ might have been adopted. V. N. Koshlyakov

Courtesy Referativnyi Zhurnal, USSR

5032. McRuer, D. T., and Krendel, E. S., The human operator as a servo system element, Parts I and II, *J. Franklin Inst.* **267**, 5, 381–404, May 1959; **267**, 6, 511–536, June 1959.

This paper considers the role of human elements in certain closed loop control systems. A quantitative description of human dynamics useful to control system designers is essential to understanding and analysis of such systems. Accordingly, the human behavior description must be expressed in terms which are compatible with conventional descriptions of control system components. This compatibility is achieved by the use of a quasi-linear mathematical model for the human operator. The model is composed of two components—a describing function and remnant. The describing function, which for a linear system is identical with the conventional transfer function, is established to characterize that portion of the operator's output which is linearly correlated with his input. The input, upon which the describing function is based, is selected on the basis of *a priori* estimates of the nature of certain human nonlinear behavior. Human output power which cannot be characterized by the operation of the describing function on the input is designated as the remnant.

After presenting the analytic basis for measurements of human dynamics, steady-state describing functions measured by the various experimenters in the field are discussed and the adaptive, optimalizing behavior of the human operator is demonstrated. The remnants are also discussed and plausible sources for their origin are postulated.

Knowledge of the range of parameter adjustment of which the human operator is capable in his adaptation as well as knowledge of his criteria for adjusting these parameters enables the designer to specify input functions and operator-controlled dynamics compatible with both desirable human operator behavior and good system performance. By judiciously trading off system complexity

against operator preferences, while still making proper engineering use of the human operator's adaptability, a control system may be optimized for both performance and reliability.

From authors' summary

5033. Slap, J. K., Recording and processing test data, *Control Engng.* **6**, 9, 177–184, Sept. 1959.

Tables, Charts, Dictionaries, etc.

(See Rev. 5342)

Elasticity

(See also Revs. 5057, 5059, 5067, 5069, 5070, 5071, 5083, 5085, 5101, 5110, 5112, 5125, 5126, 5151, 5202, 5483)

Book—5034. Chmelka, F., and Melan, E., Introduction to strength of materials, 4th revised ed. [Einfuhrung in die Festigkeitslehre, Vierte, umgearbeitete und erganzte auflage], Wien, Springer-Verlag, 1960, viii + 369 pp. $7.60. (Paperbound)

This book is the fourth edition of the "Introduction to strength of materials," which first appeared in 1946 and re-edited twice in a period of two years. This edition is increased by sixty pages more content than the last edition. The general character of the book has remained unchanged, the only new contribution being the insertion of the official Austrian standards. This book may be regarded as a classical introductory book for the engineering undergraduate student in the field of strength of materials. It deals with strength of materials from the theoretical point of view, assuming the material to be mathematically ideal. Each of the authors is well known, and especially the senior one, from their contributions in the field of theory of elasticity and plasticity. They have succeeded in the main to deal with straightforward problems of elasticity as clearly as possible and to minimize mathematical manipulations within the constraints of providing essentials to understanding.

After a simple and comprehensive introductory note on the basic concepts of the analysis of stress and strain within the elastic limit, the first chapter is devoted to the examination of tension and compression tests in isotropic and anisotropic materials. The strength characteristics in fatigue are also mentioned at the end of the chapter and a paragraph is added concerning the criteria of failure of the materials.

The three following chapters deal with bending. The second chapter introduces the notion of moment of inertia and gives the basic formulas related to these moments. The next two chapters examine cases of loading in pure bending or bending with shear as well as cases of composite loading in tension or compression with bending. These chapters are followed by one devoted exclusively to the examination of deflection curve and its various applications.

The case of torsion of cylindrical and prismatic bars and beams of various sections is contained in a rather brief section and it is followed by another one, dealing with buckling of columns in the elastic as well as in the plastic region. The final chapter concerns the solution of statically indeterminate systems. Simply and multiply indeterminate systems are examined and the equation of Clapeyron is developed and applied to simple cases.

All chapters are illustrated with a large number of examples worked out in a clear and exhaustive manner, which enables the less experienced reader to master these problems. The problems are mostly taken from practice so as to illustrate the application of the theory in the solution of design problems.

Minor criticisms are the almost complete lack of bibliography and perhaps the lack of some tables for quick reference at the end of the book giving typical values of the characteristic properties for a range of engineering materials.

P. S. Theocaris, Greece

Book—5035. Landau, L. D., and Lifshitz, E. M., Theory of elasticity (Course of Theoretical Physics, Vol. 7), (Translated from the Russian by J. B. Sykes and W. H. Reid), Reading, Mass., Addison-Wesley Publishing Co., Inc., 1959, viii + 134 pp. $6.50.

According to the preface, this text on elasticity theory is written primarily for physicists. This may make it seem curious that there are no discussions of subjects, such as dislocation theory, which involve microscopic views of matter. Some omissions make it rather unsuitable as a text for nonphysicists. For example, there is virtually no discussion of proper formulation of or available methods for solving boundary-value problems.

The book is divided into four chapters. Chapter I, Fundamental equations, covers the basic equations of linear elasticity and thermoelasticity, Boussinesq's solution for the half space, and the theory of contact. Chapter II, The equilibrium of rods and plates, covers elementary analyses of these and shells, and fills over one third of the book. Chapter III, Elastic waves, is a short description of the elements of vibration theory. Chapter IV, Thermal conduction and viscosity in solids, introduces the Maxwell and Voigt materials and contains a qualitative discussion of internal damping, including effect of thermal conductivity.

J. L. Ericksen, USA

5036. Wolf, H., Determining the stress gradient and the stress gradient parameter as occurring on notched structural elements (in German), *Forsch. Geb. Ing. Wes.* **25**, 2, 63–66, 1959.

The stress gradient and the stress gradient parameter characterize the principal stresses of a notched structural element.

$$\text{Stress gradient} \qquad \chi^x = \frac{1}{p}\frac{\partial p}{\partial s}$$

$$\text{Stress gradient parameter } \theta = \rho \cdot \chi^x$$

where s is measured along lines of principal stress p and ρ is radius of curvature of this respective line. θ can be very useful in photoelastic methods.

Analytical method is given for a symmetrical notched flat bar under simple tension and in pure bending. The results are represented in several curves. S. Sarkadi Szabo, Hungary

5037. Atsumi, A., Stresses in a circular cylinder having an infinite row of spherical cavities under tension, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 87–92, Mar. 1960.

Generalizing a perturbation scheme used previously by Chih-Bing Ling [*Quart. Appl. Math.* **13**, p. 381, 1956; AMR **9**(1956), Rev. 1730], author determines the stress concentration induced by an infinite array of equidistant spherical cavities of equal size, centered on the axis of an elastic circular cylinder which is under axial tension at infinity. Illustrative numerical results for the stress-concentration factor are given. E. Sternberg, USA

5038. Dixon, J. R., Stress distribution around a central crack in a plate loaded in tension; effect of finite width of plate, *J. Roy. Aero. Soc.* **64**, 591, 141–145, Mar. 1960.

Local stresses are determined photoelastically for a plate with narrow central slot terminated by small holes. Study relates immediately to fatigue tests on cracked plates, AMR **11**(1958), Rev. 4029. Curves of stress-concentration factor against nondimensional slot width are given in which the test results are shown in good agreement with theoretically derived stresses for finite plate width, based on an extension of Coker and Filon's analysis: "A treatise on photoelasticity," [Camb. Univ. Press, 1931].

Reviewer believes paper would benefit from fuller discussion of related works such as Westergaard [*J. Appl. Mech.* **6**, 2, A49–53, June 1939]; and recent fracture mechanics studies such as Irwin [AMR **11**(1958), Rev. 4479]. C. E. Turner, England

5039. Newcomb, T. P., Thermal stress behaviour in brake drums, *Engineering* **189,** 4899, 369–370, Mar. 1960.

Expressions are determined for stresses generated during a single brake application, and graphs showing the stress behavior for some typical automobile drums are given.

From author's summary by L. E. Goodman, USA

5040. Freudenthal, A. M., Thermal stress analysis and Grueneisen's relation, *J. Appl. Phys.* **31,** 2, p. 434 (Letters to the Editor), Feb. 1960.

5041. Clark, S. K., and Hess, R. L., Transient thermal stresses by an analogy, *J. Appl. Mech.* **25,** 4, 627–628 (Brief Notes), Dec. 1958.

Authors propose an analogy between controlled water-vapor diffusion in organic materials and the transient thermal stress problem. In organic materials swelling is linearly proportional to small water-vapor concentration differences, as thermal expansion is proportional to temperature. Differential equations that govern diffusion and heat conduction in homogeneous isotropic solids are the same.

Authors present the comparison of the theoretical solution for thermal stresses in a strip heated on its edges with the photoelastically measured results in the diffusion analogy, showing excellent agreement. Only CR-39 and Castolite materials were investigated for the one-dimensional case.

Authors suggest that three-dimensional solutions are possible.

H. Majors, Jr., USA

5042. Washizu, K., A note on the condition of compatibility, *J. Math. Phys.* **36,** 4, 306–312, Jan. 1958.

Castigliano's theorem is a variational principle for determining that particular equilibrated set of stresses which is compatible with the stress-strain relations of linear elasticity theory. The main result delivered by the principle is that the strains satisfy St. Venant's conditions of compatibility. Southwell's paradox consists of the fact that, if we express the equilibrium of the stresses, not by the differential equations, but by one of the known forms of general solution of those equations, Castigliano's theorem then delivers some, but not all, of the conditions of compatibility.

The author resolves this paradox neatly by observing that St. Venant's conditions are not fully independent. They result from linearization of the condition $R_{ijkl} = 0$ for a flat space; since R_{ijkl} satisfies Bianchi's identities, a counterpart of these results, also in the linearized case. As the author notes, these simple identities are easily verified as exact properties of the linear tensor, the vanishing of which yields St. Venant's equations. The author shows that in virtue of these counterparts of the Bianchi identities, St. Venant's equations can be divided into two sets of three, such that the vanishing of one set in the interior and of both sets on the boundary implies the vanishing of the other set in the interior. When the arguments leading to Southwell's paradox are examined, it is found that they, in effect, transfer one of these sets of equations to the boundary; by the author's theorem, it follows that both of the sets are in fact satisfied.

C. Truesdell, USA

Courtesy Mathematical Reviews

5043. Niedenfuhr, F. W., Torsion analysis of multicell tubes, *J. Aero/Space Sci.* **27,** 4, 308–309 (Readers' Forum), Apr. 1960.

Using the membrane analogy the author discusses the classical torsion analysis and by means of an example proves its utility for even very-low-aspect-ratio wing structures.

J. G. Bouwkamp, USA

5044. Dutt, S. B., Note on the torsion of a curved rod of circular cross section with transverse isotropy, *Indian J. Theor. Phys.* **6,** 4, 91–96, Dec. 1958.

The problem of the torsion of a curved rod of circular cross section with transverse isotropy has been investigated. An exact solution has been obtained by introducing a single stress function satisfying a partial differential equation which has been solved with the use of toroidal coordinates.

From author's summary by K. H. Griffin, England

5045. Rivello, R. M., The yield strength and deflection of circular bars subjected to torsion, *J. Aero/Space Sci.* **26,** 12, 836–837 (Readers' Forum), Dec. 1959.

5046. Bassali, W. A., Torsion of beams whose sections are bounded by certain quartic curves, *J. Mech. Phys. Solids* **7,** 4, 272–281, Oct. 1959.

Cauchy integral methods are applied to the torsion of a solid isotropic cylinder whose section is bounded by a quartic curve which is the inverse of an ellipse with respect to any point on its major or minor axis. The mapping function is $z = c\zeta/(1 + n\zeta + m\zeta^2)$ $c > 0$, $-1 < m < +1$. The complex torsion function, the torsional rigidity and the shearing stresses are explictly determined in the case, and particular values are found to agree with those already known for Booth's lemniscate ($m = 0$) and the elliptic limacon ($n = \pm 2\sqrt{m}$). The distribution of shearing stress on the boundary is computed in two particular examples. By the analysis, the boundary curve, taken in the z plane, can be mapped on the unit circle γ in the ζ plane, as usual.

S. Sarkadi Szabo, Hungary

5047. Storey, C., Investigation into one of the assumptions of the Hertz theory of contact, *Brit. J. Appl. Phys.* **11,** 2, 67–68, Feb. 1960.

Shtaerman's generalization of the Hertz contact problem to cases in which the dimensions of the contact surface are no longer small compared to the appropriate radii of curvature of the bodies is examined for the contact of two spheres and of two cylinders. Some numerical results are included.

Author appears to be unaware of the paper by C. Cattaneo, [*R. C. Mat. Univ. Roma*, **6,** 504–512, 1947] which deals with the problem of two spheres. H. Deresiewicz, USA

5048. An, B., Elasticity problem in the case a rigid sphere is pressed on the plane surface of semi-infinite elastic solid, *Bull. JSME* **3,** 9, 47–53, Feb. 1960.

The present paper is a continuation of a previous paper of the same title. Here the author investigates the stress distributions at an interior point of a semi-infinite elastic solid when a rigid sphere is pressed on the plane surface of the solid. Using the values of displacements and stresses obtained by applying Hankel's transform [see Sneddon's "Fourier Transforms"], author solves the problem (a) neglecting friction and (b) assuming friction on the contact surface. Graphs are drawn with different values of ν to show that the magnitude of the shearing stress increases with the decrease of Poisson's ratio. D. N. Mitra, India

5049. Duffy, J., A differential stress-strain relation for the hexagonal close-packed array of elastic spheres, *ASME Trans.* **81** E (*J. Appl. Mech.*), 1, 88–94, Mar. 1959.

This is one in a series of papers, initiated about ten years ago by R. D. Mindlin, whose aim is to construct a theory of the mechanical behavior of granular media based on the response of individual granules to forces at their contact with neighboring granules. This response is computed by means of an extension of the classical Hertz theory of contact accounting for tangential as well as normal stiffness of each contact.

In the present paper the medium is idealized by a model con-

taining like elastic spheres in a hexagonal close-packed lattice. The local response at each contact being, in general, a function of the entire past history of loading, the author limits his analysis to a derivation of differential stress-strain relations, applicable to problems involving stress increments which are small compared with the initial (isotropic) stress. These relations are shown to have elastic symmetry of the hexagonal crystal class. (In this connection the following misprint may be pointed out: in the numerator of the expression for c_{44}, Eq. [11], read 984ν for 948ν.)

In application of the theory, author computes the velocity of (long wavelength) compressional waves in a "granular" bar and compares it with experimental values. He finds that the predictions of the present theory represent a considerable improvement over those of a theory based on consideration only of the normal components of the contact forces (and the use of the Hertz theory of contact). H. Deresiewicz, USA

Viscoelasticity

(See also Revs. 5100, 5149, 5202)

5050. Saroja, Mrs. B. V., Creep deformation, *Aircr. Engng.* **32,** 372, 34–36, Feb. 1960.

Creep deformation and stress distribution in a homogeneous, isotropic, thin rotating disk with central circular hole operating at a uniform elevated temperature are analyzed using Mises-type stress-strain rate relation and associated yield criterion. (Same problem was analyzed by Wahl et al using other types of stress-strain rate relations: AMR **7**(1954), Rev. 2156; AMR **9**(1956), Rev. 3244; AMR **10**(1957), Rev. 2066.) Yield criterion utilized here depends in specified manner on radial coordinate. Derivation of this yield criterion, and its meaning for a homogeneous material, is not discussed. Stress distribution for a particular sized disk is computed utilizing a numerical successive approximation scheme, and then creep strain rates are determined. Results obtained agree well with Wahl's experimental and analytical findings.

J. Sackman, USA

5051. Oding, I. A., and Lepin, G. F., Calculation of effective stresses in a ring specimen subjected to creep and relaxation, *Indust. Lab.* **24,** 7, 947–951, July 1959. (Translation of *Zavod. Lab., SSSR* **24,** 7, 845–848, July 1958 by Instrument Soc. Amer., Pittsburgh 22, Pa.)

A split ring used for creep and relaxation studies is analyzed. Creep results from loads tending to separate cut ends of ring; relaxation results from insertion of a calibrated wedge in the gap. Method of measuring the stress is not clear. Ring is shaped to produce nearly uniform bending. Calculations of stress distribution presented are based on elastic-plastic stress-strain relations. It is concluded that stress in outer fibers decreases, approaching 2/3 the nominal elastic stress, as deformation increases. An effective stress is calculated. W. N. Findley, USA

5052. Findley, W. N., Creep and relaxation of plastics, *Mach. Design* **32,** 10, 205–208, May 1960.

The reliability of plastic structures and parts are predicted with the aid of selected test data and empirical equations.

From author's summary

5053. Stussi, F., On the relaxation of steel wires (in German), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 273–286, 1959.

It is suggested that the relaxation phenomenon of steel wires, such as are used in prestressed concrete, should be evaluated by means of the same expression as that suggested by the author some time ago for the variation in the fatigue strength of metals under frequently repeated loads. The excellent agreement between this calculation and the experimental results is indicated. The effect of the creep of the concrete on the relaxation of the steel is examined. Since the suggested expression correctly determines the shrinkage and creep of concrete, the long-time strength of timber and steel, and also the settlement of foundations, it may well be characterized as a general law for such long-time phenomena.

It is suggested that the relaxation of stressed steel wires is underestimated in present-day building regulations.

From author's summary

5054. Malinin, N. N., Regularities of creep in metals and calculation of creep in design of machine elements (in Russian), *Vestnik Mash.* **39,** 1, 6–14, Jan. 1959.

Author reviews various methods of approach in the calculating of machine elements subject to creep; he does not go into metallurgy. Literature references, mainly Russian, cover 27 items. An equally bent beam, turbine blades and turbine disks are treated as examples; the latter criticises the results of Wahl [*J. Appl. Mech.* 1956 and 1958]. Mathematical derivations are omitted; formulas and graphs are given.

Afterdeformation and relaxation, both under load as a function of time, are distinguished. The linear middle portion of the (e_p,t) curve may be approximated in the case of afterdeformation by $\dot{e}_{p\min} = k\sigma^n$ in which e_p is plastic part of the elongation, σ one-dimensional tension, k and n constants.

At constant temperature three creep hypotheses avail:

(1) Strengthening $\quad f_1(e_p, \dot{e}_p, \sigma) = 0$

(2) Flow $\quad f_2(\dot{e}_p, \sigma, t) = 0$

(3) Ageing $\quad f_3(e_p, \sigma, t) = 0$

of which the first is most acceptable, the other two fail in alternate load problems when the zero point of time is not considered.

An ageing hypothesis by Beljajew, formulated $e_p = \sigma \int_{0+t} k\sigma^{n-1}dt$ and modified by author, however, gives good agreement with the mathematically difficult strengthening theory.

Following are the results given for a bent beam:

$$\sigma = M_x[y]^{1/n} \cdot I_{nx}^{-1}$$

$$\text{curvature} = (M_x I_{nx}^{-1})^n \Omega(t)$$

and for a rectangular section:

$$I_{nx} = 2^{(-n-1)/n} \cdot n \cdot (2n+1)^{-1} \cdot bh^{(2n+1)/n}.$$

Evaluation of the results of different hypotheses follows.

N. B. Van Albada, Holland

5055. Sharma, S. K., Rotation of a plane lamina in a viscoelastic liquid, *Appl. Scient. Res. (A)* **9,** 1, 43–52, 1959.

The steady flow produced by a rotating disk in a viscous fluid was studied by Th. von Kármán in a classical paper [see, for instance, Sect. 6.6 of the treatise by Dryden, Murnagham and Bateman [AMR **12**(1959), Rev. 1349)]. Author deals with the similar problem for a viscoelastic fluid (with a relaxation and a retardation time) defined by an equation of state which is "dynamically consistent" in the sense of Oldroyd [AMR **4**(1951), Rev. 212]. One of the conclusions is that "elasticity" reduces the frictional moment on the disk; the result applies, however, only to a hypothetical fluid specified by a very particular choice of the many parameters which enter even in a simplified equation of state, and Oldroyd has shown that seemingly trivial changes in that equation may lead to conflicting results. G. Capriz, England

5056. Morland, L. W., and Lee, E. H., Stress analysis for linear viscoelastic materials with temperature variation, Brown Univ., Div. Appl. Math. TR 1 (Contract NOrd 18594), 40 pp., Sept. 1959.

With temperature-dependent relaxation or retardation times, a body with nonuniform temperature is mechanically inhomogeneous.

Even with incompressible material and steady-state temperature distribution, problem is difficult. Solutions are obtained in case of tube with different internal and external temperatures, loaded by step increase in internal pressure, with either no external support or an elastic casing. Results from Kelvin and Maxwell models indicate that nonuniform temperature has a pronounced effect. A. C. Pipkin, USA

5057. Gohlke, W., On the relationship of the modulus of elasticity to the rate of deformation (in German), *ZVDI* **102**, 13, 516–522, May 1960.

The effect of the rate of deformation on the stress-strain curve of specific materials poses the question of whether the zero point slope of this curve and, consequently, the modulus of elasticity of the materials are related to the rate of deformation. Two methods were evolved, by means of which the modulus of elasticity can be determined when there are rapid changes in form. In the speed ranges investigated it could not be established that the modulus of elasticity of steel and duralumin was related to the rate of deformation. From author's summary

Book—5058. Creep and recovery (Seminar on creep and recovery of metals, 38th National Metal Congress and Exposition, Cleveland, Ohio, Oct. 6–12, 1956), Cleveland, Ohio, American Society of Metals, 1957, iii + 372 pp. $7.50.

This book covers the subject of creep from various points of view and should be primarily of interest to metallurgists, solid-state physicists and chemists. The book is based upon a seminar and includes fourteen different papers. The first part of these proceedings deal with various aspects of creep recovery including thermodynamics, defects, and the recovery of various physical and mechanical properties. The last part is concerned with interaction of dislocations and vacancies, grain boundary behavior in creep of crystalline metals, theories of creep, creep-rupture behavior, and creep of crystalline nonmetals. J. Marin, USA

Plasticity

(See also Revs. 5045, 5051, 5104, 5114, 5132, 5140, 5179, 5189)

5059. Pawelski, O., and Lueg, W., The elastic-plastic bending of round bars and its application to the process of straightening in three-roll straightening machines (in German), *Stahl u. Eisen* **29**, 25, 1852–1862, Dec. 1959.

The bending moment in an elastic-plastic round bar under uniaxial stress is calculated. Knowing the stress-strain curve of the material, it is found that when the center fiber of the bar attains yielding, the surface fibers of only 40% of the mid-length of the bar have been plastically strained. Subsequently, the deflection configuration of the bar is graphically determined.

The theory is applied to the case of straightening round bars in a three-roll machine. The effects of the roll radius of curvature, bar diameter and distance between rolls on the deflection curve and the straightening force are determined. Curves are given for the selection of the most favorable machine setting for a given roll curvature.

These results are verified satisfactorily by experiment. The observed higher straightening forces are ascribed to friction not incorporated into the theory. D. Kececioglu, USA

5060. Eason, G., The elastic-plastic bending of a compressible curved bar, *Appl. Scient. Res.* (*A*) **9**, 1, 53–63, 1959.

Problem considered is pure bending of a wide curved bar under conditions of plane strain. Expressions for displacements are derived using Hooke's law, with arbitrary values of Poisson's ratio for elastic regions, and Tresca yield condition and flow law for plastic regions. Solutions are given for the following four possible cases: (a) completely elastic bar, (b) plastic zone at intrados only, (c) elastic core surrounded by plastic zones at both intrados and extrados, (d) fully plastic bar. Since Poisson's ratio occurs in several equations in the form of a simple multiplier, certain numerical results of Shaffer and House dealing with an incompressible material can be easily adapted to any value of Poisson's ratio. B. Paul, USA

5061. Budiansky, B., and Mangasarian, O. L., Plastic stress concentration at a circular hole in an infinite sheet subjected to equal biaxial tension, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 59–64, Mar. 1960.

An infinite sheet with a circular hole is subjected to biaxial tension; the resulting stress state is discussed on the basis of J_2 deformation theory of plasticity, assuming strains as small and the variation in thickness as negligible. Using the extended Michell theorem, Poisson's ratio is taken as 0.5 to calculate the stresses. A feature of the paper is the transformation used to eliminate the space variable, leading to a direct calculation of stress-concentration factor, without knowing the stress-state throughout. Materials characterised by power law of Ramberg-Osgood for uniaxial stress-strain curve are studied. There is a discussion justifying the use of the deformation theory within certain ranges. G. A. Nariboli, India

5062. Mangasarian, O. L., Stresses in the plastic range around a normally loaded circular hole in an inifinite sheet, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 65–73, Mar. 1960.

The expansion of a circular hole in an infinite sheet, a problem much discussed, is studied on lines similar to an earlier paper (see review above). Analysis based on both the deformation and the incremental theories is given. Elastic strains are taken into account. Comparison with a similar earlier solution shows good agreement in the regions of negligible variation in thickness. Stress at the hole being the most important, reviewer feels that a comparison in the region of variable thickness would have been more revealing. G. A. Nariboli, India

5063. Ivlev, D. D., Discontinuous solutions of space problems in the theory of ideal plasticity, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22**, 4, 669–677, 1958. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Paper considers possibility of satisfying the stress equations of plasticity (yield criterion and two equations of quasi-static equilibrium) for axial symmetry when surfaces of stress discontinuity are allowed. Close analogy with corresponding plane problem [Prager, Courant Anniversary Volume, 1948] is indicated. Consideration is given to pyramidal plastic mass of which faces define discontinuities. No problems are solved. The velocities of flow are not mentioned. S. J. Tupper, England

5064. Druyanov, B. A., Limit analysis of a plastic nonhomogeneous wedge, *Soviet Phys.–Doklady* **4**, 4, 916–918, Feb. 1960. (Translation of *Dokladi Akad. Nauk SSSR* (*N.S.*) **127**, 5, 990–992, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

A rigid, ideally plastic, infinite wedge is loaded by a uniform pressure on one edge, the other edge being free. Using the Tresca yield condition, with the assumption that the yield stress at a point in the wedge is an exponential function of the polar angle at that point, the plain strain solution is presented in terms of quadratures. A brief outline and discussion of the velocity field is also presented. D. Frederick, USA

5065. Ivlev, D. D., On relations defining plastic flow under Tresk's condition of plasticity and its generalizations, *Soviet Phys.–Doklady* **4**, 1, 217–220, Aug. 1959. (Translation of *Dokladi*

Akad. Nauk SSSR (N.S.) **124**, 3, 546–549, Jan./Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The yield condition of maximum shearing stress for a perfectly plastic material was first proposed by Tresca (the effect of a double transliteration renders this name "Tresk" in the title). It is very simply written in terms of the principal stresses but becomes quite complex in terms of the stress components. Here the author considers the special case where two of the principal stresses are equal ($\sigma_1 = \sigma_2$) and derives the equations for stresses and velocities in an arbitrary coordinate system. The characteristic manifold $\chi(x, y, z)$ for the velocity equations is shown to be $F[2F^2 - (\nabla\chi)^2] = 0$ where $F = n_i(\partial\chi/\partial x_i)$ and n_i are the direction cosines of the third principal stress direction. This is exactly the same form as the manifold for the stress equations derived by the author in an earlier paper [*Prikl. Mat. Mekh.* **22**, 1, 1958].

A similar treatment is then given to a "loose material" (soil?) where the maximum shearing stress depends on the mean normal stress. P. G. Hodge, Jr., USA

Rods, Beams and Strings

(See also Revs. 4991, 5036, 5044, 5046, 5051, 5059, 5060, 5088, 5095, 5098, 5109, 5178, 5182, 5189, 5464)

5066. Nüsken, F., Horizontal draw-bar under bending influence of its own weight (in German), *Dtsche. Eisenbahn Tech.* **8**, 3, 110–112, Mar. 1960.

This very elementary problem in strength of materials is treated in most textbooks in a more general way and discussed more thoroughly than is done here. Reviewer believes that the article is lacking in research value and displays no originality in the treatment of the subject. J. J. P. Geerlings, Holland

5067. Heller, S. R., Jr., Brock, J. S., and Bart, R., The stresses around a rectangular opening with rounded corners in a beam subjected to bending with shear, David W. Taylor Mod. Basin Rep. 1311, 27 pp., Mar. 1959.

Paper is devoted to the study of the general case of a rectangle with rounded corners. The solution presented is based on the usual assumptions of plane elasticity, and is valid for an opening "small" relative to the web, edge of the opening remote from the applied loads, and small displacements. The opening is assumed centered on the origin of the coordinate axes. The solution is obtained by the Muskhelishvili's complex-variable method together with the conformal mapping technique.

Curves giving typical tangential stress distribution around the boundary, location of the maximum stress, maximum stress concentration factor as function of the aspect ratio and corner radius, are presented. Numerical values cover a wide range of cases of practical interest.

The effect of a small eccentricity is studied in the Appendix. C. A. Sciammarella, Argentina

5068. Schultz, H. G., Moment distribution by Cross' method for arbitrarily curved members of variable moment of inertia (in German), *Schiffstechnik* **6**, 30, 35–41, Feb. 1959.

Formulas for the determination of fixed end moments and stiffness factors of arbitrarily curved members of variable moments of inertia have been derived by introducing an auxiliary value B for moment of inertia. The influence of the curvature of the member upon the distribution of the bending moment in the frame is shown in an example and it is compared with the distribution obtained on an idealized frame with straight members.

From author's summary by D. D. Vasarhelyi, USA

5069. Rvachev, V. L., On bending of an infinite beam on elastic half-space, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 5, 984–988, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

This paper deals with the application of solutions of a three-dimensional contact problem of a strip to the analysis of an infinite beam resting on an elastic foundation. Instead of the commonly used Hertz theory, this paper assumes that between the deflection $u(x, y, 0)$ and the load $p(x, y)$ the following relationship holds

$$u(x,y,0) = \frac{1-\nu_0^2}{\pi E_0} \iint_{(S)} \frac{p(\xi,\eta)\,d\xi\,d\eta}{\sqrt{(x-\xi)^2+(y-\eta)^2}} + kp(x,y)$$

R. M. Evan-Iwanowski, USA

5070. Rvachev, V. L., On the pressure under an infinite beam resting on an elastic half-space, *Appl. Mech. Math. (Prikl. Mat. Mekh.)* **23**, 2, 565–567, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

In two earlier papers, author found the equation for elastic curves of infinite beams resting on an elastic half-space and also the contact pressure distribution between a beam and the elastic half-space that will produce a sinusoidal deflection curve. The beams were assumed to bend only in the longitudinal direction. Utilizing these results, author presents the solution of the subject problem for the case when the beam is loaded by a concentrated load. Numerical calculations are carried out for a specific example and the results are compared with those from a paper by Gorbunov-Posadov (not available to reviewer). Apparently in that paper a simplifying assumption was made, that is, at any given cross section the contact pressure distribution across the width is the same as that of a rigid flat die indenting a two-dimensional half-space. As might be expected, the more refined analysis of the subject paper yields results which are only slightly different. K. N. Tong, USA

5071. Dutt, S. B., Torsion of a circular cylinder of varying rigidity with isotropic core (in English), *Atti Accad. Sci. Torino, Cl. Sci. Fis. Mat. Nat.* **93**, 1, 117–123, 1959.

Paper concerns the determination of the stress and strain state in a circular-cross-section bar with rigidity varying with its radius, surrounding a circular concentric core of constant rigidity. The circular bar is subjected only upon its lateral surface to tangential loads which are normal to the generatrix direction and vary along its length; in this way an axisymmetrical twist takes place.

Problem is solved by series the terms of which are produced between modified Bessel functions and trigonometric functions. P. P. Teodorescu, Roumania

5072. Buchert, K. P., Minimum cost design of large support rings, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 5 (*J. Struct. Div.*), 25–38, May 1960.

There is suggested a method of design for large support rings. The method proposes that the outer flange plate of the ring can be eliminated on various sections of the ring without materially affecting the ring stresses. Significant savings in the fabrication cost of the ring can thus be realized. From author's summary

5073. Siev, A., Design of unsymmetrical reinforced concrete sections, *J. Amer. Concr. Inst.* **31**, 10, 1059–1070, Apr. 1960.

Design of unsymmetrical sections of I and T shapes such as those used for roof purlins are studied in this paper. The maximum stresses in such unsymmetrical sections become nearly the same as in symmetrical T sections if the major principal axis coincides with the plane of loading. A method of determining this axis and its angle of deviation from an assumed axis in cracked-elastic and cracked-plastic stages is presented. Design equations are derived and an example is given. K.-H. Chu, USA

5074. Schneider, J., A practical method for determination of load-distributing effect of lateral ribs (in German), *Schweiz. Bauztg.* **78,** 5, 63–65, Feb. 1960.

The structural design of high buildings frequently calls for ceilings with reinforcing ribs. In case of an excessive load on one rib, the problem arises either to reinforce this rib or to estimate the distribution of the load over lateral ribs. Based on simplified assumptions, a method is shown to estimate this load distribution. The method is based on the known theory of beams on elastic foundations. The analytical derivation of the equations is followed by formulas for practical applications, with diagrams for coefficients for various load distributions. A numerical example is also given. B. Levenetz, USA

5075. Ikeda, S., Elastica of wire rope under tension (in English), 9th Congrès Intern. Mécan. Appl., Univ. Bruxelles, 1957; **6,** 209–220.

This paper deals with the intriguing problem of the ultimate configuration of an initially kinked wire rope. The rope may flop about and straighten when pulled or may take the form of a progressively smaller-radius kink. Author deals with parts of this problem in terms of an equivalent wire.

Also included are handy calculations converting multi-stranded cables into an equivalent wire with corresponding elastic properties. R. A. Burton, USA

5076. Nosek, S., Theory of strength of woven materials, Part 1: Stress distribution in tensile tests (in German), *Faserforsch. Textiltech.* **10,** 12, 573–577, Dec. 1959.

To attack the problem mathematically author makes the principle assumption that a rectangular membrane may be considered instead of a piece of fabric. After solution of the equilibrium equations in partial derivatives of second order, further simplification is adopted so that the lines of the membrane perpendicular to the direction of breaking load remains straight, at least at the moment that the fabric is about to break.

Under such assumption the author derives the equations of deformation of the fabric in infinite series, containing hyperbolic functions, and gives indications as to the border outline of the specimen under load and also to the stresses arising in longitudinal transverse and diagonal directions. He also illustrates the concept graphically, using space diagrams. The author admits further that the experiments do not confirm his deduction that maximum stresses would arise at the edges of the membrane at the clamps because, in fact, the fabric breaks at the center of the specimen. He considers peculiarities of the real fabric structure and concludes that both the elasticity model and Poisson's constant should be different at different points of the specimen of real fabric under the breaking tests. This would explain the discrepancy between theory and experiment. Z. S. Szaloki, USA

Plates, Shells and Membranes

(See also Revs. 5027, 5061, 5062, 5076, 5091, 5100, 5113, 5139, 5197, 5483, 5534)

5077. Daniel, H., and Richter, W., Model analysis of an elastically supported oblique plate (in German), *Bauingenieur* **34,** 10, 406–407, Oct. 1959.

Rubber supports are frequently used nowadays for plate bridges. The paper reports briefly on model tests on a skew plate with equal sides and angle of skew 40°, loaded by a transverse concentrated force and placed, first on rigid simple supports, then on parallel elastic supports simulating actual rubber supports. The results are shown to be nearly the same in both cases.

C. E. Massonnet, Belgium

5078. Serebryanyi, R. V., The deflection of a thin semi-infinite plate resting on an elastic layer of finite thickness, *Soviet Phys.–Doklady* **4,** 2, 460–463, Oct. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **125,** 4, 752–755, Mar./Apr. 1959 by Amer. Inst. Phys., Inc., New York, N.Y.)

Deflection of plate in title problem is investigated under any pressure distribution. Value of the article would have been greatly enhanced by numerical examples. H. D. Conway, USA

5079. Stenesku, K., A mixed problem of bending of elastic plates (in Russian), *Rev. Mech. Appl.* **4,** 1, 149–157, 1959.

Author investigates bending of a laterally loaded plate defined by any simple closed contour with "continuously varying curvature" with any mixture of clamped and free boundary conditions. Problem is reduced through use of conformal transformation and analytic continuation to a problem of the Hilbert type in an infinite complex plane cut along certain arcs of the unit circle (the transformed free portions in the boundary). Author is led thus to a solution in the form of a power series in the transformed complex variable. R. W. Leonard, USA

5080. Knowles, J. K., and Reissner, E., Torsion and extension of helicoidal shells, *Quart. Appl. Math.* **17,** 4, 409–422, Jan. 1960.

The problem of rotationally symmetric deformation of a thin elastic shell with mid-surface a portion of a right helicoid is discussed, with particular reference to a uniformly pretwisted thin strip subjected to equal and opposite axial forces and torques. The theory is based on equations derived elsewhere by the same authors. A fundamental aspect of the problem is the dependence of certain rotationally symmetric states of strain on nonsymmetric displacements. The relation of applied forces and torques to twist and extension is discussed and explicit results obtained which generalize work by Chen Chu.

R. Tiffen, England

5081. Sibiryakov, V. A., Calculation of orthotropic conical shell for arbitrary external load, using the method of V. Z. Vlasov, *ARS J.* **30,** 1, 78–82 (Russian Supplement), Jan. 1960. (Translation of Izv. Vysshych Uchebnykh Zaveydenii MVO, Aviationnaya Tekhnika no. 2, 72–82, 1959.)

Paper is concerned with nonrotationally symmetric deformations and stresses in a shell forming a frustum of a cone, assuming that Poisson's ratio is zero. The work is an application of Vlasov's semi-momentless theory which neglects the meridianal bending couple and the twisting couple. The circumferential and shear components of strain of the middle surface are also neglected. Making still other approximations, based on the assumption that the shell thickness is small compared to other dimensions, and separating variables by expanding all quantities in appropriate Fourier series in the circumferential coordinate, author derives a fourth-order ordinary linear differential equation for the general Fourier coefficient of the circumferential component of displacement.

An approximate solution of the homogeneous differential equation is expressed in terms of Bessel functions of order one with complex argument, and a special series solution is obtained for the nonhomogeneous equation. Numerical results for stresses are worked out for a special type of normal load distribution which varies in both the circumferential and axial directions. Two types of edge conditions are considered. R. A. Clark, USA

5082. Gerasimov, I. S., On a dynamic similarity problem for a conical shell, *Soviet Phys.–Doklady* **4,** 2, 306–308, Oct. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **125,** 5, 989–991, Mar./Apr. 1959 by Amer. Inst. Phys., Inc., New York, N.Y.)

A circular conical shell of infinite length is acted upon by a uniform normal pressure spreading from the apex at constant speed v along the generating lines. Putting Poisson's ratio equal

to zero, equations of motion are reduced to a single equation of sixth order. Boundary conditions are stated for the "supersonic" case $v > c$ and for the "subsonic" case $v < c$, where c is velocity of propagation of dilatational waves in the shell. No solutions are offered. H. Parkus, Austria

5083. Sanders, J. L., Jr., An improved first-approximation theory for thin shells, NASA Rep. 24, 24 pp., June 1959.

In improving the two main classes of linear theories of thin shells most attention has been paid to Love's second approximation, whereas Love's first approximation theory is mostly neglected. In the present paper an improved first approximation theory is derived which removes the well-known inconsistency of Love's equations, namely that the strains do not all vanish for small rigid-body rotations of the shell.

This remarkable result has been achieved without complicating essentially the system of fundamental equations. Using the principle of virtual work, which takes into account the work done during a small rotation about the normal of the shell, author has found happy combinations of stress unknowns, which enabled him to reduce the number of these unknowns from 10 to 8.

The compatibility equations for the strain quantities lead easily to expressing the stress resultants and couples in terms of a set of stress functions.

An appendix gives the equations of the new theory for a circular cylinder. V. Vodicka, Czechoslovakia

5084. Chronowicz, A., The application of column analogy to the design of shells, Parts I, II, III, and IV, *Civ. Engng., Lond.* **54,** 633, 326–328, Mar. 1959; **54,** 634, 477–479, Apr. 1959; **54,** 635, 623–625, May 1959; **54,** 636, 763–765, June 1959.

The strength calculations of shells by means of differential equations is not favored by many engineers for a number of reasons. The author of this paper explains a method not requiring the use of differential equations which is called "the beam method," applicable to long shells which could be regarded as large beams spanning between traverses with the arched membrane acting as the compression boom while the lower part of the section is transmitting the tension stresses. The method is applicable only to shells with the ratio of the longitudinal span to the chord of the vault greater than 1.5; otherwise the differential-equations method is the only method available. Author shows that the computations could be carried out by the Cross column analogy explained in the book by Cross, Hardy, and Morgan, "Continuous frames in reinforced concrete," Wiley, 1932. Author illustrates the method in a numerical example of a "feather edge" shell, where the calculations are arranged in tabular form and the results are illustrated in numerous graphs.

It must be mentioned that the problem and the method are not adequately explained in this series of articles. Fortunately, the author published at the same time a book on the subject, "The design of shells; A practical approach," London, Crosby-Lockwood & Sons, Ltd., 1959, where in all probability the missing information is contained. T. Leser, USA

5085. Reissner, E., The edge effect in symmetric bending of shallow shells of revolution, *Comm. Pure Appl. Math.* **12,** 2, 385–398, May 1959.

Author studies edge effect in symmetric bending of shallow shells of revolution with simply supported or clamped edge. Only restriction is absence of radial load. By clever analysis, author shows existence of two boundary layers. Within layer associated with nonlinear membrane action, previously established by him [*J. Math. Mech.* **7,** 121–140, 1958; AMR **12** (1959), Rev. 4396], there lies a narrower layer associated with nonlinear bending action. Order of magnitude of bending stresses in latter layer are investigated for stipulated edge conditions. Specific results are given for spherical shell. C. N. DeSilva, USA

5086. Muller, W., Derivation of the elasto-static equation for rotational shells from the minimum principle of variational calculation (in German), *Öst. Ing.-Arch.* **12,** 1/2, 59–65, Nov. 1958.

The equilibrium equation of the classical theory of shells of revolution has been derived from the principle of minimum of complementary work. W. Urbanowski, Poland

Buckling

(See also Rev. 5189)

5087. Gardner, W. H., Jr., and Kline, D. H., Charts for design of reinforced concrete columns, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 5 (*J. Struct. Div.*), 1–13, May 1960.

Curves are presented which enable the designer to immediately determine the necessary size and reinforcing for a given thrust and moment. The curves are based on the ultimate strength of the column section and cover six column sizes for each of three concrete strengths. The curves are directly applicable to square tied columns with eccentricities about one axis.

From authors' summary

5088. Lauletta, E., Elastic instability of tapered pillars variously restrained (in Italian), *G. Gen. Civ.* **97,** 4, 257–264, Apr. 1959.

Buckling loads are computed for cantilever columns whose lateral dimension varies linearly over the height. Computational results are presented in graphical form.

G. W. Housner, USA

5089. Schnell, W., and Fischer, G., Buckling value calculation for plates subject to nonuniform thermal stress by method of collocation (in German), Dtsch. Versuchsanstalt Luftfahrt Ber. 78, 35 pp., Nov. 1958.

Wing-like structures are approximated by equivalent rectangular tubes. The temperature distribution is assumed to be independent of the axial coordinate x of the tube and to be symmetric with respect to principal axes (y, z) in the cross section of the tube. All cross sections are assumed to remain plane. The stress due to the temperature distribution is computed by elementary means. Boundary stresses are removed by method of superposition and by employing Saint-Venant principle. For a parabolic temperature distribution in y (flange direction) and in z (web direction), flange stresses σ_1 and web stresses σ_2 are parabolic in y and z, respectively.

Using these results, author considers the buckling of the web and flange as equivalent plate problems. Buckling loads are computed by the following methods and comparison of results by the different methods is given: (a) Energy method, (b) Galerkin method, (c) Infinite series method, (d) Matrix method, (e) Collocation method.

In general, author claims method (e) yields sufficiently accurate results for practical purposes from a second-order determinant. In other methods, the degree of the determinant varies with the degree of approximation. Reviewer believes that technique presented is a practical tool for approximating buckling loads of plates. A. P. Boresi, USA

5090. Grigolyuk, E. I., On buckling of thin shells beyond the elastic limit (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 3–11, 1957.

In the first half of the paper the author gives a detailed and useful review of the existing literature on the stability of shells beyond the elastic limit. He refers to twenty publications, eight of which are in Russian. In his own theory, author assumes initially that the material is incompressible in the elastic region, and that

at every point of the material active deformations occur. Corrections for compressibility are introduced later. On the basis of this deformation theory and using variational methods, author derives physical relations concerning stresses, strains, displacements, and potential energy, before and after the loss of stability. From these relations author further derives the basic differential equations controlling the phenomenon. Finally, author analyzes the problem using Prandtl's plastic flow theory and compares the results with the ones previously obtained.

T. Leser, USA.

5091. Vol'mir, A. S., On the stability of dynamically loaded cylindrical shells, *Soviet Phys.–Doklady* **3**, 6, 1287–1289, June 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **123**, 5, 806–808, Dec. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper investigates the case when the curved edges of a cylindrical panel are brought together at a given velocity which is small as compared to the velocity of sound in the material.

The deflection is approximated by the initial buckled shape of a flat rectangular panel with simply supported edges. The stress function of the middle plane is determined by integration of the differential equation for large deflections of a thin shell. Galerkin's method applied to the differential equation for the deflection then leads to an ordinary nonlinear differential equation of the second order for the amplitude. This equation has been integrated by means of an analog computer for a given initial eccentricity and a fixed velocity of the edges. It is shown that both for a flat and for a cylindrical panel the load increases significantly beyond the static buckling load before steady nonlinear oscillations occur. In these oscillations the mean value of the compressive stress for a cylindrical panel may reach negative values.

J. F. Besseling, Holland

5092. Galambos, T. V., Influence of partial base fixity on frame stability, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 5 (*J. Struct. Div.*), 85–108, May 1960.

The buckling strength of a pinned-base rigid frame is considerably lower than that of an identical fixed-base frame. In current design practice in the United States, however, pinned column bases are specified for most structures because the construction of suitable foundations for fixed bases usually increases the overall cost. It is shown that the rotational restraint offered by commonly used "pinned" column bases is sufficient to increase the buckling strength of these frames to almost that of identical fixed-base rigid frames. From author's summary

Vibrations of Solids

(See also Revs. 4993, 5004, 5035, 5082, 5089, 5091, 5110, 5308, 5533)

Book—5093. Tong, K. N., Theory of mechanical vibration, New York, John Wiley & Sons, Inc., 1960, xii + 348 pp. $9.75

This book is written for a two-semester theory-centered course in mechanical vibration for college seniors and graduate students. Background in differential equations and undergraduate mechanics is assumed. Emphasis is on analytical aspects and material is covered in more mathematical detail than is usual in vibration texts. Exercises appear in each chapter but answers are not given. Little prior knowledge of vibration is required but some degree of mathematical maturity is indispensable.

Chapter headings with major topics in parentheses are: 1. Systems with a single degree of freedom (damped vibration, forced vibration, complex numbers, general external force, transfer function, indicial response, piecewise linear systems, seismic instruments); 2. Systems with two degrees of freedom (normal modes, influence coefficients, Rayleigh's quotient, vibration of damped systems, forced vibration, zero and repeated roots in frequency equation, shaft whirling, vibration absorbers); 3. Systems with several degrees of freedom (generalized coordinates, matrix and tensor notation, eigenvalue problem, forced and transient response, semi-definite systems, matrix iteration, matrix deflation, enclosure theorem, symmetrization of general eigenvalue problem, Holzer's method, electrical analogs, electro-mechanical systems); 4. Vibration of elastic bodies (longitudinal vibration of slender bar, torsional vibration of shaft, lateral vibration of bar, vibration of membranes and flat plates, formulation by integral equation, Rayleigh-Ritz method, forced vibration of elastic bodies, wave phenomena, method of finite differences); Appendix. Outline of matrix algebra.

Reviewer feels that book is valuable for those who wish more mathematical sophistication and intend to pursue higher studies. It is carefully written with emphasis on intensity rather than breadth of coverage and also has the virtue of being less terse and more understandable than many mathematical texts which cover similar material.

Equation 20 on page 14 should not have the exponent of 1/2 under the radical sign. R. B. McCalley, Jr., USA

5094. Payne, L. E., and Weinberger, H. F., A Faber-Krahn inequality for wedge-like membranes, AFOSR TN 60-416 (Inst. Fluid Dynam. Appl. Math., Univ. Maryland TN BN-202), 15 pp., Mar. 1960.

It is shown that among all membranes lying in a wedge $0 \leq \theta \leq \pi/\alpha$, $\alpha \geq 1$ and having given value of $\iint r^{2\alpha} \sin^2 \alpha\theta \, r \, dr \, d\theta$, the circular sector of angle π/α has the lowest fundamental mode. This leads to lower bounds for the fundamental frequency of any membrane. From authors' summary

5095. Flekser, M. Sh., On transverse vibrations of bars, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 5, 980–983, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

Solutions for the vibrating bar taking into account the effects of rotary inertia and shear forces on the deflections are given for the following cases:

(1) Vibrations of an infinite bar acted upon by an arbitrary external force.

(2) Elastic deflections of a bar which is vibrating as a result of a constant concentrated suddenly applied force.

R. M. Evan-Iwanowski, USA

5096. Dubinkin, M. V., Vibrations of plates, taking rotatory inertia and shear into account (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 12, 131–135, Dec. 1958.

Making use of Ufliand's partial differential equations for the vibrations of thin plates, taking into consideration the effects of rotatory inertia and shearing, the problem of free vibrations of an unloaded rectangular plate freely supported on two opposite sides and the two other sides free, clamped or freely supported, is treated. For the solution of the governing differential equations the method of the expansion in series of eigenfunctions is used. In the case of a loaded plate the deflection of the plate during vibration is taken in the form of a double series. It is shown that in this case there exists for each pair m, n three frequencies and three eigenfunctions. Further, the problem of vibration of a plate freely supported on the sides under the effect of an instantaneous impulse is treated. The calculation is given for a square plate with the coefficient of the cross section $k = 5/6$, Poisson's ratio $= 1/6$, for three ratios $b/a = 0.2$; 0.1 and 0.05. The diagrams for the displacement and bending moment are plotted. It is shown that the effects of rotatory inertia and shearing decrease the displacements and especially the bending moments.

D. Raskovic, Yugoslavia

5097. Goodwin, A. J. H., The design of a resonance changer to overcome excessive axial vibration of propeller shafting, *Inst. Mar. Engrs., Trans.* **72,** 2, 37–78, Feb. 1960.

The resonance changer is a tuned damper consisting essentially of a bottle filled with oil. It is attached to an oil-filled space between the thrust collar and block. By changing its design it is possible to vary the effective mass of thrust end or its stiffness, and to insert damping into the system, thus varying the natural frequencies and response.

An analysis of the ideal response using "fixed points" is given to optimize the design to obtain minimum response throughout the operating range. Also test results using the device on various ships are given. Finally a procedure is outlined to design a suitable device for a given set of operating conditions. Very interesting paper.

A. H. Church, USA

5098. Gladwell, G. M. L., and Bishop, R. E. D., The vibration of rotating shafts supported in flexible bearings, *J. Mech. Engng. Sci.* **1,** 3, 195–206, Dec. 1959.

Authors consider axially symmetric system composed of a uniform or nonuniform flexible shaft rotating in flexible bearing. Authors use the concept of "receptance" (and not that of "mobility") to link subsystems. The free and forced vibrations are extensively discussed in the case of flexible bearings whose mass is negligible and in the case of flexible bearings with mass. The influence of damping, own weight, initial bend or unbalance, and stability conditions are investigated. It is also shown that for massive bearings the characteristic functions are not orthogonal.

G. V. Tordion, Canada

5099. Butler, D. J., Vibrations of an infinitely long cylindrical shell in a semi-infinite acoustic medium, *J. Ship Res.* **3,** 3, 41–49, Dec. 1959.

Paper investigates the forced and free vibrations of a cylindrical tube immersed in a fluid bounded by a plane surface. Generalized coordinates corresponding to the modes of free vibration of the tube are used, and formulas are obtained for the response due to forcing pressures which vary sinusoidally with time and with distances around and along the cylinder. Numerical results are given for a number of simple forcing pressure distributions and for the natural modes of the immersed cylinder. Comparison with the corresponding results for an infinite medium shows only small differences for the case when the weight of the cylinder is one fourth that of the displaced fluid. The accuracy of the numerical results is very carefully examined.

W. S. Hemp, England

5100. Naghdi, P. M., and Orthwein, W. C., On axisymmetric vibrations of thin shallow viscoelastic spherical shells, AFOSR TN 59–109 (Univ. Mich. Res. Inst. TN 5; ASTIA AD 210 389), 27 pp., Jan. 1959.

Paper is concerned with transverse vibrations of shallow viscoelastic spherical shells subjected to axisymmetric loads harmonic in time. Steady-state solution is obtained for an unlimited viscoelastic shell subjected to an oscillating load uniformly distributed over small circular region about the apex. Numerical results for axial displacement and stresses are obtained for two special media (Maxwell and Kelvin) as well as for elastic shell, and comparison is made with known results.

From authors' summary by C. N. DeSilva, USA

5101. Ambraseys, N. N., On the shear response of a two-dimensional truncated wedge subjected to an arbitrary disturbance, *Bull. Seismol. Soc. Amer.* **50,** 1, 45–56, Jan. 1960.

The paper consists of a theoretical investigation of the shear response of a truncated two-dimensional elastic wedge subject to an arbitrary disturbance. Expressions are derived for the deflections and shears which develop in the wedge owing to an imposed time-dependent disturbance. The frequencies of the wedge are derived for the six first modes of oscillation and are given graphically for different degrees of truncation for the one- and two-dimensional cases. The solution derived is applicable to earthquake engineering problems, in particular to those dealing with the seismic stability of earth dams and embankments. The concept of strong ground motion spectra is introduced and its advantages and limitations are discussed briefly.

From author's summary by Y. Sato, Japan

5102. Bronner, A., Vibrational behaviour of a wood cutting machine (in German), *Werkstattstech. Maschinenbau* **50,** 4, 183–188, Apr. 1960.

5103. Makarov, A. I., and Shetler, V. V., The balancing of high-speed centrifuges (in Russian), *Nauchno-Issled. Trudi Mosk. Tekstil'n. In-ta* **19,** 54–64, 1958; Ref. Zh. Mekh. no. 6, 1959, Rev. 6035.

The conditions are described governing the balancing of spinning centrifuges and a new type of apparatus is proposed for carrying out the dynamic balancing at working speeds. It was demonstrated by means of concrete examples that separate balancing of centrifuge rotors at reduced speeds generally gives much smaller values for the dynamic loads at working speeds; for with changes of the velocity of rotation of the flexible shaft not only do changes occur in the forces acting on the dynamically equivalent (calculation) rigid shaft but also in the points of application of the forces; thus each velocity of rotation corresponds to a special position of the planes of nonequilibrium. As a consequence centrifuges equilibrated on low speed machines such as, for instance, Shitikov's, will be found to be out of balance when used at working speeds. Besides, the vibrations of the flexible shaft depend on the rigidity of the bearings and their construction, points not considered in individual balancing. Consideration has also to be given to the appreciable reciprocal influence exerted by the bearings in relation to vibration. Therefore the balancing of centrifuge rotors should only be undertaken in groups at working speeds. The action of the proposed equilibrating apparatus is based on the proportionality of the amplitude of the vibrations of the bearing produced by its forces and on the constancy (at constant velocity) of the displacement between the centrifuge shaft direction and the inertia force causing this deflection. The apparatus enables the amplitude of the vibrations of the bearing to be determined in any direction. The transmitter is an ordinary adaptor of a transducer, fastened to the body of the bearing and creating, during vibrations, an electromotive force in the measuring circuit. The measurement of the emf is carried out on a millivoltmeter. Plans of the apparatus are furnished and the experimental results and the calculation formulas are given.

V. N. Geminov

Courtesy Referativnyi Zhurnal, USSR

Book—5104. Ruzicka, J. E., edited by, Structural damping (Colloquium on Structural Damping held at ASME Annual Meeting, Atlantic City, N. J., Dec. 1959), New York, American Society of Mechanical Engineers, 1959, iv + 165 pp. (Paperbound)

The purpose of this book is to gather information on structural damping that is useful in engineering design into one convenient reference. The authors of the different sections of the book are authorities in the field and have collected their present and past studies to present historical background and state of art in their particular areas of interest.

In section one B. J. Lazan defines damping and classifies various damping mechanisms. Component parts of system and configuration damping are analyzed considering certain structural damping mechanisms that are of particular interest. The many units and nomenclature used in material damping are classified in terms of absolute energy units or energy ratio units and the rela-

tionships among these units are defined. The several types of mechanisms involved in material damping are explained and the importance of these mechanisms in various types of materials and in various regimes of testing variables clarified. It is concluded that, in general, internal friction mechanisms do not contribute significantly to total damping at stresses and other conditions of engineering interest. If damping is to be used as an engineering design property, then the magnetoelastic and plastic strain mechanisms are probably the most important. Damping caused by plastic strain is small at low and intermediate stress. As stress increases plastic strain mechanism generally becomes more important and begins to dominate at stresses approaching fatigue limit. Representative values for damping of various types of materials and factors involved in their engineering interpretation are presented.

In section two L. E. Goodman describes some of the interesting current research in energy dissipation through interfacial slip at contact surfaces of structural and machine joints. Emphasis is placed upon work conducted outside USA. Restricting attention to cases in which gross motion does not occur, he distinguishes between partial interfacial slip, in which a certain minimum exciting load is required to initiate slip, and that in which slip begins as load is applied to the joint. In latter class it appears that energy dissipation is proportional to the cube of difference between minimum and maximum applied loads and is independent of mean load for a variety of joints. It is conjectured that this is the case whenever area of slip region is proportional to applied load. The former class of joints is more complex because load which initiates slip constitutes an additional parameter. These joints seem to be characterized by existence of an optimum clamping pressure which maximizes damping energy. At extremely high or extremely low clamping pressures little energy is dissipated.

In section three D. Ross, E. E. Ungar and E. M. Kerwin, Jr. present a general method for analysis of damping effectiveness of a number of layers of viscoelastic and elastic materials applied to an elastic plate. The damping is attributed to the extensional and shear deformations of the viscoelastic layers. The theory is used to obtain an analytical solution for a general two-layer treatment in which one or both layers may be viscoelastic. Specific results are then given for a number of practical damping treatments, including: (a) homogeneous layers, such as automotive undercoat; (b) damping tape, as used on aircraft; (c) multiple damping tapes; (d) "spaced" damping treatments; and (e) sandwich plates with dissipative cores. Estimates are made for the maximum amount of damping than can be achieved as a function of the relative dimensions of the treatment, and some relationships are presented for the design of optimum treatments. Experimental data for several of these types of damping treatments confirm the theory.

In section four T. J. Mentel uses what he calls a simplified theoretical analysis to show that while longitudinal interface motion at beam supports can produce a significant increase in total energy dissipation only for unusually thin beams, the same mechanism can produce an overriding effect for panels of average dimensions. This mechanism relies on the use of a viscous bonding material which is capable of absorbing considerable amounts of energy without breakdown or other deterioration, whose mechanical properties are selectable to a certain degree, and which is strong enough so that structural integrity may be achieved with narrow joints. If structural design parameters are suitably optimized, the energy dissipation at supports of a panel may be made to exceed the inherent material damping by several orders of magnitude. Results of preliminary experimental tests are also discussed.

In section five R. Plunkett discusses methods of damping measurements and limitations imposed by assuming a single-degree-of-freedom system and by assuming certain types of linearity. Various approaches that might be used for different applications where these assumptions do not hold are introduced and some of the errors resulting from them are indicated. It is concluded that, for greatest usefulness to other engineers, size, shape, frequency and stress level of specimen should be reported. If results are to be convincing, some proof should be offered to show that bulk of energy dissipation takes place in the specimen and not in apparatus used.

In section six J. Marin and M. G. Sharma present an extension of a fatigue strength-damping criterion previously developed by Marin and Stulen. Present investigation considers only internal or material damping and its significance in design. Local resistance of members subjected to resonant or near-resonant vibrations is a function not only of fatigue strength but also damping constant and modulus of elasticity of material. The material with best fatigue strength is not always the best material for resistance to resonant loading conditions. Four aspects of the subject are covered: 1. Design of resonant members at normal temperatures for simple fluctuating stresses. 2. Design of resonant members at elevated temperatures for simple stresses. 3. Design of resonant members for combined stresses. 4. Selection of materials for resonant load applications.

Resonant strength for various types of members is tabulated.

All sections give references. Section seven is a selected bibliography on structural damping listing one hundred references alphabetically according to author's name as well as chronologically for a given author.

Each of the sections forms an individual paper of great interest.

E. R. Steneroth, Sweden

5105. Kobrinskii, A. E., On the theory of damping by impact (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 5, 15–29, May 1957.

This paper gives a straightforward analysis of a vibration damper consisting of a bouncing ball in a cylinder with closed ends. Attached directly to the "mass" of a "spring-mass" system, this device acts as a damped nonlinear absorber. Analytical results along with experimental verifications are given.

R. A. Burton, USA

5106. Snowdon, J. C., Dynamic mechanical properties of rubber-like materials with reference to the isolation of mechanical vibration, *Noise Control* **6,** 2, 18–23, Mar./Apr. 1960.

5107. Loiseau, H., Vibration exciters and pickups with a compensating system for mass and stiffness (in French), *Rech. Aéro.* no. 60, 23–27, Sept.–Oct. 1957.

In order to study nodal patterns, damping properties and other resonance characteristics of light-weight, flexible, lightly-damped structure, it is desirable to use an exciter-measuring system which will not affect significantly the stiffness-mass-damping distribution of the structure. Author proposes the use of electromagnetic exciters and induction-type pickups mounted on cantilevers of variable length which can be tuned to frequency of the structure, thus matching the impedance of the exciter or pickup to that of the structure at the measuring point. Connection between structure and exciter or pickup is a light-weight probe kept in contact with structure by a static bias force supplied by cantilevers.

Paper describes some physical characteristics of the vibration exciters (to 3-kg-force amplitude) and the vibration pickups.

D. Muster, USA

5108. Iorish, Yu. I., Soviet papers on the study of vibration. Survey, *Soviet Phys.–Acoustics* **5,** 3, 269–281, Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 263–274, July/Sept. 1959 by Amer. Inst. Phys., New York, N.Y.)

Wave Motion and Impact in Solids

(See also Revs. 5048, 5049, 5249, 5464)

5109. Li, W. -H., Elastic flexible cable in plane motion under tension, *ASME Trans.* **81** E (*J. Appl. Mech.*), 4, 587–593, Dec. 1959.

The motion and stresses of a non-Hookian elastic flexible cable in plane motion under tension are described with four simultaneous quasilinear, partial differential equations which are totally hyperbolic. The propagation of the longitudinal elastic waves and the transverse waves is described by the four characteristics. From the characteristic equations, solutions for simple longitudinal waves and simple transverse waves are obtained for uniform Hookian cables. The problem of an infinite string moved at one point with a constant velocity can be solved. Solutions also have been obtained for the interaction of transverse and longitudinal waves with sharp fronts.

From author's summary by G. V. Tordion, Canada

5110. Ben-Menahem, A., Diffraction of elastic waves from a surface source in a heterogeneous medium, *Bull. Seismol. Soc. Amer.* **50,** 1, 15–33, Jan. 1960.

Concentrated vertical stress is applied upon the free surface of a heterogeneous elastic half space, the material constants being the functions of depth only and their relative change very small.

Assuming periodic source of disturbance the displacement components at the surface due to P and S waves are evaluated using the definite integral representation and the contour integration as were used by H. Lamb.

When the velocity of body waves decreases with depth the free surface is in the shadow zone of the direct waves and only the diffracted waves reach it. They describe a progressive wave P and S traveling with a constant velocity equal to that of surface value and the amplitude falls by the function $\exp(-rs)\cdot r^{-1/2}$, r being the distance from the epicenter. Y. Sato, Japan

5111. Leonard, R. W., On solutions for the transient response of beams, NASA TR R-21, 33 pp., 1959.

See AMR **12**(1959), Rev. 3853.

5112. Sveklo, V. A., Solution of a dynamic problem with mixed boundary conditions in the theory of elasticity for a half-plane, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 2, 383–393, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Problem discussed is that of determining the dynamic response of two-dimensional elastic half-space to the impact of a system of rigid punches. It is assumed that friction and cohesion are negligible. The initial and boundary-value problem is reduced to the solution of a singular integral equation. This equation is in turn solved *formally*. There is no discussion of the form of the solution so that the paper is of interest only for its purely mathematical content. I. N. Sneddon, Scotland

5113. Haywood, J. H., Response of an elastic cylindrical shell to a pressure pulse, *Quart. J. Mech. Appl. Math.* **11,** part 2, 129–141, May 1958.

Author of this paper uses an approximation of a cylindrical shock wave radiated into the medium which he later shows produces a good approximation to an exact solution for both early and late times in the shock interaction process. This has the advantage over other available techniques which do not give as good a result for structural response at later times in the interaction process. This is particularly important in that maximum structural response is apt to occur at later times. Coupling between structural response and the pressure pulse was not included. Of particular interest is the simplification in the equations of motion which arises from neglecting the mass of the shell in determining structural response at all stages except at the very early times.

R. DeHart, USA

5114. Kumar, S., and Davids, N., Elastic-plastic analysis of scabbing in materials, *J. Franklin Inst.* **265,** 5, 371–383, May 1958.

Paper treats the effect of plasticity upon scabbing and presents an interesting graphical approach to the determination of the stress intensities produced in an impact-loaded material having plasticity. The analysis provides a means of arriving at a first approximation to the extent of scabbing that may occur. This first approximation, however, can only be as good as the assumption used regarding the behavior of the material under dynamic loading conditions. The procedure outlined for determining the amount of scabbing produces results which further reinforce the contention that a plastic material is less likely to scab than a material possessing no plasticity. R. DeHart, USA

5115. Livshits, L. S., and Rakhmanov, A. S., The determination of the low-temperature impact strength of metals liable to the formation and development of cracks, *Indust. Lab.* **25,** 2, 201–203, Mar. 1960. (Translation of *Zavod. Lab.* **25,** 2, 190–192, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The determination of the strain and rupture energies of specimens in their testing for impact bending at various temperatures opens the possibility of ascertaining the likelihood of the brittle fracture of steel at low temperatures in cases when the ordinary impact strength tests produce high values of a_n, and fail, therefore, to reveal the brittleness of the metal.

A high value of impact strength is an indication of a high resistance of materials to rupture in given conditions only when it consists of large values of its components: strain and rupture energies. If, however, the high values of impact strength are due to the high values of only one of these components, then the material can in such condition be liable to the appearance of a nucleus of rupture or to the rapid development of an existing crack.

From authors' summary

5116. Lavrent'yev, M. A., The problem of piercing at cosmic velocities, NASA TT F-40, 6 pp., May 1960.

Consideration is given to the cases where a hard flat surface strikes a small cylinder and also where a hard curved surface strikes a small sphere. After the collisions, both the cylinder and sphere are assumed to vaporize. It is pointed out that the results do not agree with the deductions of K. P. Stanyukovich.

From author's summary

Soil Mechanics: Fundamental

5117. Herzog, H., Settlement computations by influence diagrams (in Hungarian), *Mélyépítéstudományi Szemle* **10,** 2, 82–89, Feb. 1960.

Author describes a rapid settlement computation method, based on average compression modulus defined by influence diagrams and compression curve. These influence diagrams contribute to the easy, practical application of the method.

From author's summary

5118. Choudhury, P., Two-dimensional problem of a layer of soil resting on rigid base under different surface loads (in English), *J. Instn. Engrs., India* **39,** 6 (Part I), 605–613, Feb. 1959.

On the assumption that for sandy soils the ratio E/μ is greater than for elastic solids, the stresses have been obtained in such a layer of sandy soil resting on a rigid and perfectly rough base which are due to three types of normal loads distributed over a

finite portion of the upper surface. Numerical results are given for Gaussian and parabolic distributions of load.

From author's summary

5119. Balazsi, B., and Regele, Z., Increase of load capacity of piles by soil stabilization (in Hungarian), *Mélyépítéstudományi Szemle* **9**, 9, 413–418, 1959.

Authors describe a method whereby a considerable increase in load capacity of piles has been obtained in loose gravel and sand layers. A patented injector-type pile has been worked out by them, where the injection may be carried out succesfully by tubes going through the rammed piles. From authors' summary

5120. Osterman, J., Notes on the shearing resistance of soft clays, Acta Polytech. Scandinavica no. 263, 22 pp., (Civil Engng. and Bldg. Construction Series no. 2), 1960.

In connection with investigations of the risk of further landslides in a river valley, additional research on the strength of soft clays was carried out. Some preliminary results are reported.

The results indicate the value of common quick testing and the cohesion method, and the difficulties in establishing a unique relation between strength and effective stresses because of the secondary settlements and creep.

Some objections to the common way of using the Coulomb formula and of treating triaxial test results are raised, and modified values of the apparent angle of friction are plotted against the plasticity index. From author's summary

5121. Tan, T.-K., Secondary time effects and consolidation of clays (in English), *Scientia Sinica* **7**, 11, 1060–1075, Nov. 1958.

5122. Philip, J. R., The early stages of absorption and infiltration, *Soil Science* **88**, 2, 91–97, Aug. 1959.

Absorption and infiltration of porous media has been studied by diffusion analysis and does not predict experimental observations exactly during the initial wetting. Application of momentum analysis overcomes part of the objection. D'Arcy's law and Reynolds numbers above 2000 are used to provide critical limits from which to examine the determination of the constants in the inertia terms.

Arguments are well presented on three graphs and the author's summary adds to the understanding of the initial phenomena. It is inferred that dimensional analysis would allow application of his formulas to processes using other fluids than water.

K. N. Hendrickson, USA

5123. Polubarinova-Kochina, P. Ia., Ground water movements at water level fluctuations in a reservoir with a vertical boundary, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 3, 762–769, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York, 22, N. Y.)

Author treats the linearized free-surface problem of ground water motion in a vertical plane in a soil of infinite depth as the result of variations in water level in a reservoir. Using Laplace transformations, a solution is obtained for the case where the free surface is initially horizontal, the boundary between reservoir and soil is a vertical plane, and the reservoir water level is a specified function of time, $f(t)$. Specific solutions are presented for $f(t) = at$ and $f(t) = -H_0 \cos \omega t$. Author also considers the case where the initial shape of the free surface may be expressed as a function of the horizontal coordinate.

G. C. Wallick, USA

5124. Varunov, K. F., Vertical drainage of porous concrete (in Russian), *Gidrotekh. Stroit.* **28**, 2, 22–25, Feb. 1959.

Paper presents the technology, the permeability checking and the mounting of porous concrete pipes used as vertical drains at the Stalingrad hydroelectric plant. These vertical drains served to drain an artesian water layer located in a fine sand stratum 2–12 ft thick, at a depth of 50–80 ft below the ground level.

The characteristics of the porous concrete were: crushing strength (8 days after casting), 40 kgs per sq cm; unit weight, 1.97 kgs per cu cm; permeability, 2621.5 ft per day.

R.-J. L. Bally, Roumania

5125. Serata, S., and Gloyna, E., Design principles for underground salt cavities, *Proc. Amer. Soc. Civ. Engrs.* **86**, SA 3 (*J. San. Engng. Div.*), 1–21, May 1960.

Theoretical equilibrium relationships as substantiated by experimental studies are presented here for use in the design of salt cavities. Also included are studies on reduction of cavity volume, development of the plastic zone, and stress redistribution around the cavity as functions of cavity depth, strength of salt, and physico-chemical effects of the waste.

From authors' summary

Soil Mechanics: Applied

(See also Rev. 5124)

5126. Geldmacher, R. C., Dunkin, J. W., and Anderson, R. L., Earth motion beneath a prescribed boundary displacement, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 120–124, Mar. 1960.

Paper first describes experimental study of vertical deflection profile to 42-ft depth in subgrade below highway pavement. Vehicle used had rear tandem dual wheels carrying rear axle load of 19,330 lb, and deflections were measured at depths from 1 ft 10 in. to 42 ft 7 in. by differential transformer transducers. Results from different positions of vehicle were superposed to obtain estimated equivalent deflections under single pair of wheels.

Two-dimensional theoretical analysis is based on Muskhelishvili's work for surface trench-shaped surface displacement in plane strain.

Reviewer regrets that paper gives no information about dimensions, materials or *measured* properties of pavement, base, subbase (if any) or subgrade, and gives no indication where that information may be found. For any paper describing a research experiment to have scientific value it is essential to describe properly all relevant properties of the materials used, both natural and artificial, or to refer the reader to another source where the properties are described. Paper's value would have been greatly enhanced by observance of this elementary rule.

T. K. Chaplin, England

5127. Shvetsova, N. I., A few cases of calculations for the strength of foundations (in Russian), *Sb. Leningrad In-ta Inzh. Zh-d. Transp.* no. 158, 6–18, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1813.

Results of experiments are furnished for the determination of the carrying capacity of a sand foundation under the action of a surface load applied at an angle to the normal. The experiments were carried out in a flat trough with a stamp 8 cm in width. The foundation consisted of coarse air-dry compact sand; the angles of internal friction for this sand were determined on a stabilometer in relation to its compactness. Curves were obtained for the relationship between the tangential and normal stresses for the limiting state for various degrees of compactness of the sand. To record the deformation of the sand extensive use was made of an x-ray apparatus. The influence of eccentricity in the application of the load was not investigated. The attempt to establish a clearly defined boundary between the compacted core, produced under the stamp, and the limit of the stressed soil did not succeed. A method for the determination by calculation of the carrying capacity of the foundations is proposed. The author assigns a form to the surface delimiting the sand mass subjected to shear, consisting of two straight cuttings united by an inset consisting of a logarithmic spiral. The compacted core is represented in the form

of a triangle, where the outer line of slip shows a break, which is not confirmed by the experimental data (the author's among others). There is a comparison of the results of the experiments and of the calculations made by the proposed method.

M. V. Malyshev
Courtesy Referativnyi Zhurnal, USSR

5128. Popov, B. P., Generalized formula derived for the determination of the resistance of piles (in Russian), *Tr. N.-i In-ta Osnovanii i Fundamentov* no. 30, 111–120, 1956; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1818.

A derivation is put forward for the known formula by N. M. Gersevanov for the resistance of piles. It is shown, by applying the methods in the theory of dimensions, that this formula appears to be a generalization of a number of formulas evolved by investigators working outside Russia. Some ideas are suggested to show the possibilities of improving and widening the field of application of the formula cited. I. I. Blekhman
Courtesy Referativnyi Zhurbal, USSR

5129. Shakhnazarov, A. A., Analysis of the calculation formulas for the determination of the external pressure on casing columns (in Azerb.), *Trudi Azerb. Nauk-i. In-ta po Dobychenefti* no. 5, 294–308, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1846.

Sixteen formulas are examined for the determination of the lateral pressure on the working column of drive pipes. In the majority of cases the formulas, in determining the pressure, take into account the pressure of the soil's skeletal formation and of the liquid found in its pores. Here the pressure of the liquid is investigated as a layer pressure or the pressure of rocks, above the workings, which is taken to be a supplementary evenly distributed load. It is noted that the presence of clay layers may lead to a sharp reduction in the pressure of the rock not only close to but also at a considerable distance from the break. If no account is taken of the different factors of safety in the formulas being investigated then the results of the calculations differ only slightly.

S. A. Roza
Courtesy Referativnyi Zhurnal, USSR

5130. Konstantnaya, Z. I., Density of sand in hydraulic fill (in Russian), *Gidrotekh. Stroit.* **27**, 1, 36–40, Jan. 1958.

Author presents and analyzes numerous unit weight determinations on sand samples taken from six large hydraulic-filled earth dams situated on upper and middle Volga. A systematic increase of the absolute (dry) and relative densities with the increase of the mean size (d_{50}) and of the uniformity factor (d_{40}/d_{10}) of the sand is noted.

Results obtained may be used as an indication for designing and erecting other similar structures in the above-mentioned regions.

R.-J. L. Bally, Roumania

Processing of Metals and Other Materials

(See also Revs. 5021, 5102, 5142, 5169)

Book—5131. Taylor, H. F., Flemings, M. C., and Wulff, J., Foundry engineering, New York, John Wiley & Sons, Inc., 1959, vi + 407 pp. $9.75.

An excellent, complete, and easily readable treatment for the elementary level, though it subtly requires more of the reader than is stated in the preface. This is particularly noticeable in the lack of adequate correlation between "Nature of cast metals" and "Heat treatment." Proper emphasis is placed on "Solidification," "Risering" and "Gating;" inadequate treatment of Sand testing and control; and of Pattern and casting design. Sections on physical metallurgy and welding assume considerable prior knowledge. Drawings are graphically excellent, though they again presume familiarity with equipment. C. C. Osgood, USA

5132. Korbut, V. M., Influence of dosage of surface-active substance on the surface plasticization of a metal during drawing, *Soviet Phys.–Doklady* **4**, 1, 176–178, Aug. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S)* **124**, 1, 72–74, Jan./Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

From observation that shear stress in surface layer of wire during drawing decreases in presence of surface active lubricant, author concludes that lubricant migrates into two-dimensional surface defects. Further decrease with increasing deformation, temperature and number of molecular layers of agent on surface is regarded as support for this assumption.

To reviewer development of such defects seems unlikely under normal conditions. Observations may be explained on basis of pure surface friction only. J. H. Palm, Holland

5133. Wilcox, R. J., and Whitton, P. W., Further experiments on the cold extrusion of metals using lubrication at slow speeds, *J. Inst. Metals* **88**, 145–149, 1959–60.

Copper and two aluminum alloys possessing different strain-hardening characteristics have been cold extruded with lubrication at a slow speed (0.44 in./min), over as wide a range of die angles and extrusion ratios as was practicable. Inverted-extrusion pressures for these materials, calculated from an empirical equation derived from earlier experiments, agree with experimental values within ±7%. This equation has now been shown to be applicable over a wide range of conditions to a number of very different materials extruded cold at slow speeds. Two surface defects that occur when true lubricated flow breaks down are examined, and a possible explanation of each is advanced.

From authors' summary

5134. Strandell, P. O., Cold rolling research and theoretical methods of determining the roll pressure in cold rolling of strip (in Swedish), *Jernkontorets Ann.* **143**, 11, 725–766, 1959.

5135. McMillin, C. W., and Lubkin, J. L., Circular sawing experiments on a radial arm saw, *Forest Prod. J.* **9**, 10, 1–7, Oct. 1959.

Net power required to saw certain wood species was determined under various conditions. For flat-sawn hard maple, one formula accurately covered effects of depth of cut, direction of cut, and feed rate. From authors' summary

Fracture (Including Fatigue)

(See also Revs. 5038, 5053, 5115, 5171, 5172)

5136. Bouton, I., The statistical basis of loading spectra for fatigue design criteria, *Aero/Space Engng.* **19**, 3, 53–57, 64, Mar. 1960.

Author discusses need for statistical data to formulate fatigue loading requirements for aircraft. W. H. Sparing, USA

5137. Burns, Anne, Fatigue loadings in flight-loads in the tailplane of a Devon, Aero. Res. Counc. Lond. Curr. Pap. 472, 21 pp., 1960.

5138. Coleman, J. J., Reliability of aircraft structures in resisting chance failure, *Operat. Res.* **7**, 5, 639–645, Sept./Oct. 1959.

The probability of survival of an aircraft structure is established under the assumption that the probability distribution of exced-

ences of a stress-amplitude defined as the failure stress is a Rayleigh function; the variability of the failure strength of the population of structures has not been considered. The resulting exponential reliability function is therefore a very crude approximation.

A. M. Freudenthal, USA

5139. Katz, S. N., The effect of additional axial stresses on the fatigue strength of boiler pipes (in Russian), *Teploenergetika* no. 5, 12–16, 1960.

The results of an investigation into fatigue strength of pipes subjected to internal pressure and additional axial stress are discussed. The recommendations based on calculation are given.

From author's summary

5140. Rosenthal, D., A graphical procedure for the determination of the effect of residual stress on uniaxial fatigue limit, *Bull. Res. Council Israel* **7C**, 3, 142–146, Dec. 1959.

A simple graphical procedure based on previous findings is described to compute the effect of residual stress on uniaxial fatigue limit. Various applications are discussed and some limitations are pointed out.

From author's summary

5141. Liu, H. W., and Corten, H. T., Fatigue damage during complex stress histories, NASA TN D-256, 56 pp., Nov. 1959.

Rotating bending tests were performed on wire specimens of 2024 and 7075 aluminum alloys and of hard drawn steel. A large number of test series with two stress amplitudes applied alternately were performed. The variables studied were the ratio of the number of cycles at both stress levels and the magnitude of the lower stress amplitude, the higher stress amplitude being the same for all tests. Each test was repeated 20 times. Logarithmic mean endurances were used to check a previously published theory on fatigue damage accumulation [See Corten and Dolan, Proc. Int. Conf. on Fatigue of Metals, London 1956, p. 235, Instn. Mech. Engrs. and ASME]. Agreement with test results was good, and better than for the linear cumulative damage rule $\Sigma\, n/N = 1$. The improvement could be obtained since authors' life formula contains a stress interaction factor depending on the stress levels involved. Such a factor was also proposed by Freudenthal [IUTAM-Colloquium on Fatigue, Stockholm 1955, p. 53].

Analytical functions for the stress interaction factor were derived from the test results for the three materials tested. In the first appendix the strain-aging effect as found in the steel specimens has been considered. In the second appendix other cumulative damage theories are compared with authors' theory. The theories did not fit as well to the test results as authors' theory.

Reviewer is not fully satisfied by the physical background of the theory. However, the additional stress interaction factor does make it more flexible in adaptation to test results than the linear cumulative damage rule. The usefulness of authors' formula was shown by applying it to a test with a continuously varying load amplitude. Further work of this type is in progress. Reviewer feels that the specimen geometry and the type of fatigue loading are important variables to be studied.

J. Schijve, Holland

5142. Chaevskii, M. I., On the mechanism of the increase in the fatigue strength of elastoplastic materials which tend to harden during cyclic deformation, under the influence of strong, surface-active substances, *Soviet Phys.-Doklady* **4**, 2, 423–426, Oct. 1959. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **125**, 2, 319–322, Mar./Apr. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author shows that fatigue limit of annealed steel increases 20% by testing in a melt of Pb-Su eutectic and increases 40% by prior coating with layer of Pb-Sn eutectic, all testing done at 300 °F. He proposes a strain-hardening (Orowan) mechanism for explaining observations and illustrates changing stress and strain patterns by series of hysteretic loops. Reviewer believes that strain-hardening assumption is not appropriate at low level of cyclic stress considered by author (long fatigue life) and that strain-softening actually occurs.

B. J. Lazan, USA

5143. Kudriavtsev, I. V., and Savvina, N. M., Fatigue strength of large size strip component parts, and methods for raising such strength (in Russian), *Vestnik Mash.* **39**, 1, 42–47, Jan. 1959.

Investigation seeks to determine fatigue strength of frame components for hydraulic presses from rolled steel slabs with cross sections up to 200 × 300 mm and 50 × 75 mm mostly of steel 22 K.

A vibrating machine was composed of pendulums in a horizontal plane, forming a free swinging system that gives a constant symmetrical bending moment over the length of the test piece.

One pendulum carried an eccentric weight rotating at 1600–1800 rpm. To circular sections rotative bending was applied instead.

A ground 200 × 200-mm rectangular specimen with enlarged ends withstood 14.5 kg/mm² over 10 million cycles. A fissure once started would propagate rapidly. A 200 × 300-mm section with ends of the same size withstood only 4.5 kg/mm²; this could be improved to 9.3 and even 12.5 kg/mm² by hammering the surfaces where the specimen was clamped. Notched specimen showed similar improvement when the notch was hammered with bullets or cold-rolled.

Different shapes, sizes and types of steel confirmed the experience in a general way and are discussed.

N. B. Van Albada, Holland

5144. Oding, I. A., and Gurevich, S. E., Investigation on notch sensitiveness of some kinds of cyclic loaded steels (in Russian), *Vestnik Mash.* **39**, 1, 30–35, Jan. 1959.

In 1948 authors published in *Wjestnik Machinostroeniya* no. 1 an investigation defining notch sensitiveness ν in relation to theoretical stress concentration K_t.

Normalized steels of 42, 55 and 78 kg/mm² endurance strength are now investigated between $K_t = 1.8$ and 3.43. Specimens 6 mm round smooth and 8 mm round, notched to 6 mm, were subjected 20 million times to rotative bending. In addition to the half circular notches with parallel edges of 1948, V-shaped notches with foot radius between 0.15 and 1.00 mm were used.

Plotting test results into theoretical K_t curves in a (ν, K_σ) diagram gave a ν-value that keeps close to the average of 1.13, 1.11 and 0.73 for the three steel classes, independent of the sharpness of the notch. Here $K_\sigma \geq 1$ means the quotient of the fatigue strengths of the smooth and of the notched specimen.

Authors conclude that with overstressing (earlier fracture) the effective K'_σ decreases, the more so as notch is sharper.

N. B. Van Albada, Holland

5145. Lubahn, J. D., and Yukawa, S., Size effects in slow notch-bend tests of a nickel-molybdenum-vanadium steel, *Proc. Amer. Soc. Test. Mat.* **58**, 661–677, 1958.

Paper is an experimental study which shows the effect of size and notch radii on the fracture properties of nickel-molybdenum-vanadium steel notched bars in bending. Also influence of notch depth, temperature, hydrogen content and proximity of welds is briefly dealt with.

The important results are: (a) Notch bend strength is high for large specimen with mild notch or small specimen with severe notch. (b) Beyond a certain severity of notch the strength does not decrease very much. (c) Notch ductility decreases from 30 to 3% when size of specimens geometrically similar to standard Charpy V-notch specimens increases from 0.2 to 9 in. (d) Notch ductility increases with increasing number of successively higher loading and unloading cycles prior to fracture.

Reviewer wishes to stress the novelty of this work, particularly with regard to the large range of sizes employed in the investigation.

J. Glucklich, Israel

5146. Stuessi, F., Theory and test results on the fatigue of metals, *Proc. Amer. Soc. Civ. Engrs.* **85,** ST 8 (*J. Struct. Div.*), 65–90, Oct. 1959.

Empirical equations are presented relating alternating stress versus number of cycles in fatigue, stress versus time-to-rupture in static creep, alternating stress versus mean stress in fatigue, and stress versus time in relaxation. Interrelationships between the equations are derived, discussed and compared favorably with test data from the literature for aluminum alloys. A general case relates alternating stress, mean stress, and a number of cycles to failure of five material characteristics: tensile strength, "creep effect," and three constants describing the fatigue S-N diagram. The influence of rate of cycling, strain-hardening and stress concentration are discussed. W. N. Findley, USA

5147. Fisher, W. A. P., Fatigue tests on notched extruded aluminum alloy (DTD 364B) having a theoretical stress concentration factor of 3.65, Aero. Res. Counc. Lond. Curr. Pap. 460, 12 pp., 1960.

Fatigue tests were made in axial tension at ratios of mean to alternating stress of 1.1, 2, and 3, and at fixed mean stresses of 8800, 14,000 and 18,000 lb/in.^{2}. The tests provide data on the fatigue of alloy to DTD 364B (now L65) with a comparatively high stress concentration and also on the notch sensitivity of this material. From author's summary

5148. Minkov, Ya. L., On simplifying the form of specimens for fatigue testing of metals, *Indust. Lab.* **25,** 4, 479–482, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, 464–469, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The results of bending fatigue tests showed that the application of specimens of a simplified form, which was proposed earlier by I. V. Kudryavtsev, is convenient for steel and nonferrous metals. The influence exerted by grips can be totally eliminated by the application of localized cold working for materials having a hardness not exceeding 350 H_B. In the investigation of specimens of greater hardness, the surface cold working provides the possibility of reducing the diameter of heads and thus simplifying the form of specimens. From author's summary

5149. Oding, I. A., and Fridman, Z. G., The role of surface layers in the long-time rupture of metals under creep conditions, *Indust. Lab.* **25,** 3, 345–348, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 329–331, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5150. Akroyd, T. N. W., Ultimate loads in rock and concrete, *Engineering* **189,** 4908, 672–673, May 1960.

Experimental Stress Analysis

(See also Revs. 4991, 4992, 5036, 5038, 5041, 5077, 5148)

5151. Theocaris, P. S., Direct determination of stresses in plane elasticity problems based on the properties of isostatics, *ASME Trans.* **81** E (*J. Appl. Mech.*), 2, 227–234, June 1959.

The equations of plane elasticity are given for isostatic fields in terms of orthogonal curvilinear coordinates (functions of the complex variable, z), the appropriate magnification factor h, and the boundary conditions. For free boundaries or boundaries subjected to purely normal loads, the method applies exactly. If boundary shear stresses are present, the method applies approximately by assuming the boundary is still an isostatic.

By analogy, any potential field satisfying the proper boundary and physical conditions may be used to experimentally determine the corresponding fields of isostatics. Having these and after determining additional quantities, graphically, a numerical or graphical integration will give the stresses.

Author describes the application of an electrical analogy method using graphited paper to two examples having known analytical solutions. Comparison of results indicates good agreement.

S. F. Borg, USA

5152. Buttner, H., Mechanical stress measurement by making use of the magneto-strictive effect (in German), *Maschinenbautechnik* **8,** 3, 146–150, Mar. 1959.

5153. Elizarov, D. P., The stresses set in the flange connection of a high parameter steam pipe-line during warm up (in Russian), *Teploenergetika* no. 4, 33–38, 1960.

The results are given of experimental determination of additional stresses arising during warm up in the flange connection of a pipeline designed for high steam parameters. Some defects in the existing construction are marked off.

From author's summary

5154. Afendik, L. G., and Shekhter, L. I., An investigation of the stresses and strains in tubular tensile test samples of polycrystalline metals, in the presence of necking (in Russian), *Fiz. Metallov i Metallovedeniye* **2,** 3, 538–545, 1956; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9336.

An investigation of the strains and stresses in the necked cross section of a tensile test sample. All conclusions are drawn on the assumption that the sample may be regarded as a thin-walled shell having an axis of symmetry. The tests were made with tubular samples of annealed steels 10 and 30. The following results were obtained: (1) when tubular samples of polycrystalline metals were tested in tension until the appearance of a neck, in addition to the axial stresses, circumferential, normal stresses σ_β are also set up, as well as radial stresses σ; (2) The magnitude of these stresses depends on the ratio of the initial wall thickness of the sample to the mean diameter; (3) failure takes place at appreciably lower values of the reduction in cross-sectional area, and of intensity of stress than in the case of solid samples.

V. A. Sbeshnikova

Courtesy Referativnyi Zhurnal, USSR

5155. Konovalov, M. D., Rikhter, V. A., and Tarapin, V. N., A photoelectric instrument for measuring torques, *Measurement Techniques* no. 2, 113–114, Apr. 1960. (Translation of *Izmeritel'naia Teknika USSR* no. 2, 28–29, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Tests have shown that the calibration stays unchanged (within the error of measurement) for up to a year; the error of measurement under field conditions is 3–4%, but can be reduced to 2% under laboratory conditions; the unit works well at temperatures from – 20 to + 35°C.

These units have been in use for several years on excavators, snow-clearing machines, road rollers and other such machines.

From authors' summary

5156. Becker, H., and Gerard, G., Photoelastic model engineering, *Mech. Engng.* **82,** 7, 43–46, July 1960.

5157. Nenyukov, V. P., Zhmur, A. S., and Lyapin, G. L., A ballistic pendulum for calibrating acceleration transducers, *Measurement Techniques* no. 2, 114–116, Apr. 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 2, 29–30, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5158. Likharev, K. K., Hydraulic strain gauge for measuring strain during tension and compression, *Indust. Lab.* **25,** 3, 376–377, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 359–360, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Material Test Techniques

(See also Revs. 5051, 5143, 5144, 5145, 5174)

5159. Boklen, R., Simplified calculation of the Brinell hardness (in German), *Z VDI* **102,** 4, p. 128, Feb. 1960.

5160. Solntseva, G. A., and Yagn, Yu. I., Device for testing metals for triaxial compression, *Indust. Lab.* **25,** 3, 372-373, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 355-356, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5161. Zilova, T. K., Palkin, B. A., Petrukhina, N. I., Ryazanov, N. V., and Fridman, Ya. B., Tensile tests at varying amounts of stored elastic energy, *Indust. Lab.* **25,** 1, 79-85, Mar. 1960. (Translation of *Zavod. Lab., USSR* **25,** 1, 76-82, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5162. Lazarev, G. P., Machine for testing materials for thermal fatigue, *Indust. Lab.* **25,** 3, 374-376, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 357-358, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5163. Ral'tsevich, N. V., Fatigue-testing machine for flat specimens, *Indust. Lab.* **25,** 3, p. 374, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, p. 356, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5164. Glikman, L. A., Kostrov, E. N., and Dobrer, V. K., On corrosion fatigue tests in bending and torsion, *Indust. Lab.* **25,** 4, 472-476, Apr. 1960. (Translation of *Zavod Lab., SSSR* **25,** 4, 456-460, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5165. Lapin, A. A., Sinyavskii, U. S., and Vedenkin, S. G., Corrosion fatigue testing of metals with an electromagnetic machine of the self-oscillation type, *Indust. Lab.* **25,** 4, 476-479, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, 461-463, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5166. Baron, L. I., Kurbatov, V. M., and Orlov, R. V., Pendulum impact-testing machine for determining the rupture energy, *Indust. Lab.* **25,** 3, 379-380, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 361-362, Mar. 1960 by Instrument Society of America, Pittsburgh 22, Pa.)

5167. Stankevich, O. F., and Bondarev, Yu. E., Dynamic testing of geometrically similar specimens at low temperatures, *Indust. Lab.* **25,** 4, 487-489, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, 470-471, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5168. Kuz'menko, V. A., Experimental plant for determining the Young's modulus at high temperatures, *Indust. Lab.* **25,** 3, 368-370, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 351-352, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Properties of Engineering Materials

(See also Revs. 5052, 5057, 5106, 5131, 5142, 5145, 5147, 5499)

5169. Cremens, W. S., and Grant, N. J., Preparation and high-temperature properties of nickel-Al_2O_3 alloys, *Proc. Amer. Soc. Test. Mat.* **58,** 714-732, 1958.

Further study has been made of high strengths obtainable in range of 1300 to 1800°F from dispersion-strengthened alloys of this type. Extrusions were made from 0.2 to 0.02μ Al_2O_3 powders blended with nickel powders down to 1 to 2μ, and inter-particle spacing of the Al_2O_3 related to mechanical properties. Stress-rupture results comparable with those of more complex commercial alloys were obtained. C. W. Gadd, USA

5170. Shahinian, P., and Achter, M. R., The effect of atmosphere on creep-rupture properties of a nickel-chromium-aluminum alloy, *Proc. Amer. Soc. Test. Mat.* **58,** 761-774, 1958.

Previous findings of shorter time-to-rupture in air than in vacuum in the low-temperature, high-stress region, as well as the reverse of this (oxidation strengthening) for the high-temperature, low-stress region, were extended to include the brittle material of the title. Differences exhibited themselves chiefly in the third stage of creep, but in the tests in air at elevated temperature, the time-to-rupture increased to include a fourth stage, during which creep continued at a decelerating rate. Influence of atmosphere was related to mode of crack propagation.

C. W. Gadd, USA

5171. Clark, C. L., Rutherford, J. J. B., Wilder, A. B., and Cordovi, M. A., Metallurgical evaluation of superheatertube alloys after six-months' exposure at temperatures of 1100 to 1500 F, *ASME Trans.* **82A** (*J. Engng. Power*), 1, 35-67, Jan. 1960.

5172. Kuznetsov, V. D., and Loskutov, A. I., The effect of prior deformation on the plasticity of aluminum, *Soviet Phys.-Doklady* **4,** 3, 659-662, Dec. 1959. (Translation of *Doklady Akad. SSSR (N.S.)* **126,** 1, 70-73, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The initial sentence in this article reads, "Until recently the strength of a material was regarded as a quantity independent of the length of application of the load." This reviewer (and others) has held an opposite opinion for more than fifteen years. Apparently the content of this paper bears little reference to the opening sentence. The subject under investigation is whether ALL changes produced in a metal by cold working are removed by annealing. Tests on copper and on aluminum demonstrate that there are irreversible effects. It is shown that although the ultimate strength remains constant after various degrees of cold working followed by annealing, the deformation to failure is continuously decreased by larger amounts of cold working. This is in accord with widely accepted theories of dislocation migration.

C. E. Balleisen, USA

5173. Horst, R. L., Jr., and Murphy, F. B., Aluminum alloys, *Indust. Engng. Chem.* **51,** 9 (Part 2), 1157-1160, Sept. 1959.

5174. Jaeger, J. C., The use of complete temperature-time curves for determination of thermal conductivity with particular reference to rocks, *Austral. J. Phys.* **12,** 3, 203-217, Sept. 1959.

An article covering the use of the total temperature-time curves for the determination of the thermal conductivity of solids. The procedures presented are well adapted for use in determining the thermal conductivity of rocks. The limitation in many of the other methods of studying only the asymptote of a temperature-time curve is not inherent in the proposed method. Equally spaced time intervals are used together with a curve calculated from the theory. Curves are presented for a number of situations which are useful in connection with the determination of the thermal conductivity of rock; among which are a line source in the semi-infinite solid, along the axis of a cylinder, and along the surface of a cylinder. The extension of the method to the measurement of diffusivity of solids in the form of cylinders and slabs is also presented. The paper is recommended for those interestered in the area of measurement of the thermal conductivity of solids.

G. A. Hawkins, USA

5175. Garvey, B. S., Jr., Elastomers, *Indust. Engng. Chem.* **51,** 9 (Part 2), 1167–1171, Sept. 1959.

5176. Straka, Leora E., Rubber developments, *Mech. Engng.* **82,** 4, 71–77, Apr. 1960.

Structures: Simple

(See also Revs. 4992, 4993, 5053, 5068, 5073, 5077, 5088, 5101)

5177. Robertson, R. G., The two-span haunched continuous beam in prestressed concrete, *Proc. Instn. Civ. Engrs.* **15,** 255–272, Mar. 1960.

The economical use of material in a continuous beam requires that the beam be prestrained by "secondary" moments, and provided with haunches. Equations are developed for the amount of prestrain and size of haunch for any span, loading, or stress, and any shape of section. Design graphs are given for any span, loading, and stress for use with a particular shape of section, and their use is illustrated by an example. A procedure for obtaining the cable profile which will create the desired secondary moment is described. The ultimate-load factors are calculated and compared to those calculated by plastic theory.

From author's summary by C. J. Bernhardt, Norway

5178. Havlar, Gy., Posttensioned concrete beams with nonbonded steel (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 1/2, 115–133, 1959.

In the first part of his study author deals with the structural forming of posttensioned concrete beams with nonbonded steel usually applied in engineering practice. In the following part he discusses the determination of the magnitude of interior forces depending on the strain conditions of the whole system, in comparison to the determination of interior forces of a pretensioned concrete structure with bonded steel, the interior forces of which depend upon strength and loading of the investigated structure.

After a detailed deduction of interior forces belonging to outwardly statically finite tied-beams, he passes over to the determination of interior forces of outwardly statically infinitely supported continuous beams on the basis of principles of the elasticity theory. He draws attention to the load-carrying capacity reserve available over the design head and compares it with the safety against failure of pretensioned concrete beams with bonded steel.

From author's summary

5179. Menyhard, I., Calculation of arch-girders of perfectly plastic material (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 1/2, 153–160, 1959.

Author in his present paper solves a simple problem referring to the determination of forces arising in a two-hinge arch of constant cross section, loaded at its crown by a single force. The material of this arch is assumed to be perfectly plastic. From this example it may be concluded that if the arch is not too oblate, and the load acting on it causes considerable bending moments, then the possibility of a compensation of moments could come into being, and at the same time compression forces could be neglected. However, the necessary conditions and the complete proof of this statement require further investigations.

From author's summary

5180. El-Demirdash, I. A., The continuous Vierendeel girder (in German), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 47–63, 1959.

As the points of contraflexure of the Vierendeel girder do not coincide with the centers of the members, it is not permissible to calculate the internal forces and moments of the Vierendeel girder by introducing hinges at the centers of the members. The hinged system does, however, give almost the same deflections as the statically indeterminate Vierendeel girder. These deflections are, in the main, dependent on the moments and direct forces. The deflection contributions δ_M and δ_N associated with them correspond approximately to the deflections of a simple beam due to shear forces or to bending moments. They are of the same order of magnitude and must therefore both be taken into account.

For the calculation of the redundant reactions at the supports of a continuous Vierendeel girder with chords of equal stiffness the internally statically indeterminate system can be directly replaced by a statically determinate hinged system. The support reactions obtained in this way are in good agreement with the more accurate values and may be used for the subsequent calculation of the moments and direct forces for the continuous Vierendeel girder by means of the pairs of elastic forces or by the panel method. The calculation of the forces in the chords and the moments at the ends of the members of the continuous Vierendeel girder from the moments and shear forces of the continuous beam is unreliable.

From author's summary

5181. Scordelis, A. C., Internal forces in uniformly loaded helicoidal girders, *J. Amer. Concr. Inst.* **31,** 10, 1013–1026, Apr. 1960.

Paper presents lucid analysis of helicoidal stairways in reinforced and prestressed concrete. By application of strain energy method to a girder whose ends are clamped and whose elastic axis is helical in form, and by selecting base structure to reduce degree of statical indeterminacy from nine to two, generalized formulas for the two redundants are obtained and evaluated for 510 different cases, the variables being horizontal angle, angle of slope, cross-sectional dimensions, whence the two bending moments and the torsional couple are obtained. An IBM 701 digital computer was used. Results are most useful to busy practical designers.

Extensional (membrane) forces are disregarded; interaction forces of stairway and landings are not considered; hence author's elegant approach may be somewhat conservative. [A. C. Liebenberg; *Struct. Engr., Lond.*, **38,** no. 5, May 1960; see also author's paper, *Proc. Amer. Soc. Civ. Engrs.* Pap. 1756, Sept. 1958; AMR **12**(1959), Rev. 4382]. F. A. Gerard, Canada

5182. Osetinskii, Yu. V., and Nevedrov, A. T., Calculation for the deformation of a system of intersecting beams (in Russian), *Trudi Novocherk. Politekhn. In-ta* no. 69/83, 73–94, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1906.

The calculations are examined for the longitudinal-transverse deflections of a system consisting of two mutually perpendicular beams and of a system built up from three beams, two of which are parallel and the third perpendicular. Only the articulations of the linkage of the beams at intersections are taken into account. A graphoanalytical method is brought into use with the aid of the theory of matrices.

The authors are in error in their statement that similar problems have not been looked into previously, for these problems belong to the class of problems on the stability of beams on elastic supports.

I. K. Snitko

Courtesy Referativnyi Zhurnal, USSR

5183. Asplund, S. O., Theory of trusses (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 1–16, 1959.

Author develops matrix method of analyzing pin-jointed trusses, space and plane, statically determinate and indeterminate. A space truss is defined as a succession of "tripods," each fixing a new joint by 3 bars from 3 previously fixed points. If there are J joints, author writes "... general method of solution requires inversion of square matrix of same order 3J as number of bars in truss." Author proposes method of "tripods" involving successive inversion of 3×3 matrices (q) starting from highest point and working down to foundation hinges which are connected to the "tripods" by six support bars involving inversion of 6×6 matrices

(Q). Statically indeterminate trusses are analyzed by cutting appropriate bars to obtain basic statically determinate structure.

Author's method is decidedly inferior to simple elegance of matrix analysis developed by Argyris. Consider statically determinate trusses. If $\{R\}$ = column matrix of applied forces; $\{S\}$ = forces (stresses) in bars; $\{v\}$ = strains in bars; $\{r\}$ = displacements of nodes; then $\{S\} = bR$, $r = b'v$, $v = fS$, where $|f|$ = diagonal matrix of flexibilities of unassembled bars; whence $r = (b'fb)R$. No inversions are required, and $\{b\}$ is found from simple statics. For statically indeterminate trusses, one inversion only is required. [See J. H. Argyris: Die Matrizentheorie der Statik, *Ing.-Arch.* **25**, 3, p. 174; AMR **11**(1958), Rev. 81; Proc. IX Int. Congr. Appl. Mech., Sect. II, Sept. 1956, etc.] Furthermore, author is incorrect in his use of conception of duality which (analogous to duality in projective geometry) means, correctly, duality of matrix force method (*FM*) and matrix displacement method (*DM*). Thus, if F = flexibility matrix, K = stiffness matrix, both of complete structure, then $KF = FK$ = Unit matrix. Transposition of b matrix to determine displacements is still *FM*, not *DM* as author assumes. Duality in matrix form is adequately discussed by Argyris; see also elegant summary of duality by F. Stüssi in "Baustatik," Volume II, page 114, Basle, 1954. F. A. Gerard, Canada

5184. Tsai, F. -Y., Precise analysis of single-storey continuous truss bents by the moment distribution or other similar methods (in English) *Scientia Sinica* **7**, 1, 91–119, Jan. 1958.

5185. Dundurs, J., A method for analyzing deformations of plane trusses (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **18**, 1–14, 1958.

5186. Su, H. -L., Statistical approach to structural design, *Proc. Instn. Civ. Engrs.* **13**, 353–362, July 1959.

Paper proposes a method for designing structures using principles of probability and statistics as a basis. Whereas the conventional method of structural design uses fixed data together with an assumed factor of safety, the proposed method starts with determination of the statistical variability of the factors involved. From this information a design is calculated which will have a specified probability of safety.

Three examples on steel work, reinforced concrete and soil mechanics are included for illustration and show that the proposed method leads to more economical design.

Reviewer considers this paper a valuable contribution to the theory of structural design. B. Langefors, Sweden

5187. Jaeger, L. G., and Chilver, A. H., The design of frameworks to give specific deflections (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19**, 81–110, 1959.

Paper investigates this problem: given external loads on a pin-jointed framework whose outline and mode of support are defined, can stiffnesses and arrangement of members be found such that loaded nodes deflect by specified amounts? Using principle of work, authors investigate simple statically determinate frameworks of given configuration; next, graphical methods are used, being more convenient for a complete framework. A short discussion of redundant frameworks follows. The third section treats of design and discusses possible arrangements of internal members to achieve required (generally, equal) deflections of (given) loaded nodes. For this purpose, basic "structural units" are devised for plane and space frames. This conception is good. Authors' presentation is lucid.

Reviewer feels, however, authors' basic approach to be inferior to, and less elegant than, the matrix force and displacement (dual) methods of Argyris. Thus, if $\{R\}$ = column vector of external forces; $\{r\}$ = displacements of nodes; $\{S\}$ = forces (stresses) in members; $\{v\}$ = strains in members; $|f|$ = diagonal matrix of flexibilities of unassembled members; then, using the force method, $S = bR$, $r = b'v$, $v = fS$, whence $r = (b'fb)R$ where $b'fb = F$ = flexibility matrix of complete structure. The required conditions follow at once. A similar analysis is available for redundant frameworks. [See J. H. Argyris: "Energy theorems and structural analysis" *Aircr. Engng.* **27**, no. 314, Mar. 1955; Proc. IX Int. Congr. Appl. Mech., Sect. II, Sept. 1956; Aero. Res. Counc. Lond., Rep. Mem. 3034, Feb. 1956; etc.] F. A. Gerard, Canada

5188. Wei, L., Analysis of span-change rigid frames by the method of propagating unbalanced moments and lateral forces (in English) *Scientia Sinica* **7**, 10, 1079–1108, Oct. 1958.

See AMR **11**(1958), Rev. 1583.

5189. Klein, B., A simple method of matric structural analysis: Part IV—Nonlinear problems, *J. Aero/Space Sci.* **26**, 6, 351–359, June 1959.

Applying the same basic approach as in his previous publications (involving the setting-up of all equations for equilibrium and deformation) the author considers a number of simple nonlinear structural problems which he solves by direct iteration. The examples analyzed are: (1) large deflection of an elliptic frame under internal pressure; (2) buckling of a spring-supported uniform strut; (3) creep of a pin-jointed frame at a uniform temperature; (4) elastic-plastic behavior of a beam subjected to transverse loads, end load, and thermal gradients; (5) efficient design of a pin-jointed frame subjected to two loading cases.

J. H. Argyris, England

5190. Pagano, M., Subject: calculation of elastic thrusting systems (in Italian), *G. Gen. Civ.* **97**, 2/3, 112–128, Feb./Mar. 1959.

The study offers a documentation of the large use made of thrusting structures formed by continuous elements on intermediate sliding supports, with their headpieces maintained by thrust bearing fastenings. The technical advantage generally increases with the number of elements but the calculation also becomes more complicated if it is done according to usual practice. A new method is, therefore, suggested, consisting of an initial phase in connection with the balancing of the thrusts and of a second phase in connection with the balancing of the moments. It permits disregarding the congruence in the second phase in connection with the balancing of the moments; in fact, a preliminary cut is made in the knot so that, for the distribution of the unbalance, the two limbs of the cut, originally in contact, still have the same rotation angle but move apart causing a disconnection in the structure. At the end of a balancing rotation, in most cases, the disconnections occur in all the knots and an intermediate operation is, therefore, necessary to restore the congruence. This supplementary operation never alters considerably the condition of the moments which rapidly reach the final values. In the fairly frequent case of structurally symmetrical elements, this intermediate operation is not necessary (notwithstanding the cut, the limbs do not show, in the balancing, a relative displacement). If the profile of the element can be analytically expressed, it is easy to obtain the elastic coefficients which appear in the calculation; the expressions concerning the lowered parabolic arches are reported in the text. Finally, two numerical examples are produced.

From author's summary

5191. Fain, Ya. S., Control of stresses in concrete arched structures and arches by means of one-sided or unsymmetrical reinforcement (self-stressed arches, etc.) (in Russian), *Tr. Saratovsk. Avtomob.-dor. In-ta* **15**, 1, 52–70, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1978.

A method is proposed for the self-stressing of concrete arches which results in the decrease of the magnitude of the tension stresses in the arch. Calculations are worked out which take into account the concrete's creep, reducing the amount of metal used.

In his investigations on the critical stresses in the ferro-concrete components the author starts with the assumptions that the cohesion between the reinforcement and the concrete is not broken; that the modulus of elasticity of the concrete becomes a constant in the course of time; that the concrete and the steel conform to Hooke's principle; that the concrete is in the first stage of the stressed state (up to the appearance of cracks indicating disruption of the concrete); and that the distribution of stresses with height in the section is rectilinear. The method is extended to cover cases of complete arches as well.

V. I. Kuznetsov
Courtesy Referativnyi Zhurnal, USSR

5192. Kordina, K., Calculation of prestressed concrete members according to the strain theory (in German), *Publ. Int. Assn. Bridge Struct. Engng.* **18,** 81–90, 1958.

This paper is connected with a study by Nik. Dimitrov: "Effects of the strain theory on prestressing" published in I.A.B.S.E. publications, 1956. Dimitrov's conclusions may be cited in brief:

"In structures in which prestressing is employed, the deformation in the concrete gives rise, according to theory, to additional second-order permanent moments..."

Author disagrees with Dimitrov's conclusions for prestressed concrete with bond, or even for posttensioned concrete, where the bond is formed by injection of grout. Author bases his opposition on theoretical considerations, in which the prestressed beam is compared to a concrete frame with a suspended tie rod; and also on the well-known fact that centrally prestressed planks and arches show no buckling effects. Since in practice it is only in exceptional cases that bond of cables to concrete is not formed, Dimitrov's conclusions can be applied to only such exceptional cases.

E. Ben-Zvi, Israel

5193. Davies, J. D., Discontinuity in circumferentially prestressed cylinders, *Civ. Engng., Lond.* **55,** 643, 225–227, Feb. 1960.

The paper gives a simplified analysis of the discontinuity effects between the prestressed and non-prestressed portions of a thin-walled cylinder during circumferential prestressing operations.

The solution is based on the known characteristics of an analogous beam on an elastic foundation and the method is particularly useful for determining the critical longitudinal bending stresses set up in the cylinder wall at the commencement and at the completion of the winding process.

Elastic behavior is assumed and the application of the method is demonstrated for a prestressed concrete pipe to compare the results with a more exact solution. From author's summary

5194. Laull, Kh. Kh., The analysis of prismatic folded structures (in Russian), *Trudi Tallinsk. Politekhn. In-ta* (*A*) no. 56, 1–28, 1954; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9261.

Examples are given of the calculation of a folded roof, a theatre balcony, and a reinforced concrete bunker, to illustrate the application of the suggested method of calculating prismatic shells (called the method of approximated shear stresses). Critical consideration is given to the method recently proposed by Craemer [H. Craemer, *J. Amer. Concrete Inst.* **2,** (1953)] for the analysis of prismatic folded structures, and the method of Kazinczy [G. Kazinezy, Intern. Verein. f. Brueckenbau u. Hochbau, IIIrd Congress, Liege, 1948] for the calculation of folded structures in the presence of cracks.

A. K. Mroshchinskii
Courtesy Referativnyi Zhurnal, USSR

5195. Ockerblom, N. O., and Kyzminov, S. A., New trends in the development of the technology of welded structures (in Russian), *Svarochnoye Proizvodstvo*, Leningrad, Lenizdat, 1957, 143–160; Ref. Zh. Mekh. no. 8, 1958, Rev. 9320.

Methods are presented for the analysis of the residual stresses due to longitudinal strains in the weld zone. The case of rollers bearing on an unstressed, flat plate in the presence of residual stresses therein is examined and the analytical determination of the strains is performed by the method already used to determine upsetting forces. Further, the process is investigated of the appearance of residual strains as a result of the application of cross-welds, special attention being directed to local deformations caused by the welding, in the form of bulging of thin sheets in the plane of least rigidity. Methods are given for the determination of torsional strains in the region of butt welds, in relation to the geometrical proportions of the sheets and the quantity of heat introduced by the welding process. Several variants of welding schedules for work-pieces composed of plates and stiffeners are discussed and comparatively evaluated; the influence of the selected sequence on the magnitude of the residual strains is examined; and arguments are presented for the necessity of applying analytical methods in the design of welded structures in order to reduce the magnitude of the residual strains. G. A. Nikolaev
Courtesy Referativnyi Zhurnal, USSR

Structures: Composite

(See also Revs. 5074, 5136, 5137, 5138, 5181, 5186, 5207)

5196. Szidarovszky, J., Approximate determination of the secondary stresses caused in bridge cross girders by the main truss chord elongations (in English), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 3/4, 335–340, 1959.

The secondary stresses in the cross girders, due to the action of chord member elongation, depend greatly on the location of the cross member with respect to the main truss, as well as on the degree of fixing of the cross members to the chord members. The author completes the known approximate calculation methods, taking into account the two effects mentioned above, and extends them to the case of skew cross members.

From author's summary by E. R. Johnston, USA

5197. Holmberg, A., Bending moments in wing walls (in Swedish), *Bygningsstat. Medd.* **31,** 1, 30–34, Feb. 1960.

Author proposes very simple approximate method for computing maximum bending moments in wing walls (supporting vertical edges of abutment main walls) of portal frame bridges. Method is based on results of exact calculations.

F. J. Plantema, Holland

5198. Owens, R. H., An elementary development of piping flexibility analysis with illustrative examples, *J. Amer. Soc. Nav. Engrs.* **72,** 1, 159–170, Feb. 1960.

This work shows the application to the practical problems of a matrix method previously developed by author [AMR **12**(1959), Rev. 5455] for treating general piping flexibility problems.

Author solves a simple coplanar system with a traditional development and with the matrix method; shows, with a simple numerical example, the chain of calculations that a digital computer must be instructed to do, and the construction and uses of the various matrices which arise in the theoretical development.

This paper is useful for the practical engineer since it makes it easy to apply the analytical method. G. Noseda, Italy

5199. Lucas, A. H., The stress analysis of railway coaches, *Engineering* **189,** 4908, 669–671, May 1960.

5200. Michelberger, P., Computation of side pieces of railway carriages and autobusses for bending (in Hungarian), *Jarmuvek Mezogazdasagi Gepek* **6,** 8, 248–255, 1959.

5201. Milne, R. D., An approximation to the influence function for plate-like wings, *Aircr. Engng.* **31,** 264, 156–162, June 1959.

A general solution for the small deflections of thin plates of slowly varying thickness under lateral loading in the form of an influence function is briefly presented. The influence function may be represented as an infinite series in terms of the eigenfunctions and eigenvalues associated with a homogeneous form of the plate differential equation.

It is suggested that the series may give an acceptable approximation to the influence function when summed over a small number of terms when also the eigenfunctions and eigenvalues involved are deduced by an approximate procedure of the Rayleigh-Ritz type.

A numerical example is given for a uniform cantilever plate, and the results are compared with experiment and with similar results deduced by an alternative theoretical procedure.

Thus the calculation of a sufficient number of approximate normal vibration modes and frequencies for the plate as normally required for aeroelastic investigations may in this way be made to serve as the basis for a complete analysis of the plate.

A simple approximate allowance for shear deflection of the plate is presented and illustrated.

From author's summary by T. H. Lin, USA

Machine Elements and Machine Design

(See Revs. 5039, 5054, 5075, 5098, 5143, 5153)

Fastening and Joining Methods

(See Revs. 5131, 5143, 5195)

Rheology

(See also Revs. 5050, 5055, 5056, 5064, 5294, 5337)

Book—5202. Eirich, F. R., edited by, Rheology, theory and application, Vol. 3, New York, Academic Press, Inc., 1960, xvi + 680 pp. $21.

This third volume is of more interest to most engineers than the first two volumes [AMR **10**(1957), Rev. 4011; **11**(1958), Rev. 4005] because of the emphasis on structural materials, industrial liquids, and applications. Sixteen topics are covered by authorities in their fields. Two theoretical chapters treat dilute polymer solutions and the types of viscometers. Other chapters include: viscosity of solutions of polyelectrolytes, rheology of latex, pastes and paints, printing inks, and lubricants. Plastics are covered by articles on crystalline and crosslinked polymers, rheology of molding, theory of screw extruders, and rheology of spinning. Inorganic materials are covered by chapters on glasses, concrete, and mixtures of water with sand or clay. Interfacial phenomena are treated in chapters on adhesion and on interfacial viscosity and elasticity. Most of the chapters are excellent summaries of the present state of knowledge in the various fields. Extensive indices and references to the literature are included. This book is highly recommended to all scientists working in any of the fields discussed.

L. Nielsen, USA

5203. Bhatnagar, P. L., and Lakshmana Rao, S. K., Steady motion of non-Newtonian fluids in tubes, Proc. Third Congr. Theor. Appl. Mech., Bangalore, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol.; Karagpur, 1957, 225–234.

Authors deal with a special type of incompressible Reiner-Rivlin fluid. Using a perturbation method, they investigate secondary flow in pipes with noncircular cross section. For the special fluids considered, the "cross viscosity" has an influence only on the perturbed flow.

W. Noll, USA

5204. Srivastava, A. C., Superposability in non-Newtonian fluids, Proc. Second Congr. Theor. Appl. Mech., New Delhi, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol., Kharagpur, 1956, 187–194.

Author deals with a special type of incompressible Reiner-Rivlin fluid. Two flows possible for such a fluid are called superposable if the flow obtained by adding the velocity fields and the body force fields of the two flows is also possible. Author derives lengthy conditions under which superposability holds. Reviewer believes that these conditions are almost never satisfied.

W. Noll, USA

Hydraulics

(See also Revs. 5223, 5224, 5274, 5294, 5309, 5324, 5325, 5326, 5502, 5505, 5508)

5205. Vainshtein, A. L., On the measurement of the discharge of viscous media, *Measurement Techniques* no. 1, 75–80, Mar. 1960 (Translation of *Izmerital'naia Tekhnika, USSR* no. 1, 58–62, Jan. 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

5206. Mukhlenov, I. P., and Tarat, E. Ya., Hydraulic resistance of grids (in Russian), *Zh. Prikl. Khimii* **31**, 4, 542–549, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6521.

Results are given of the experimental investigation on the hydraulic resistance of the dry grid of a sieving apparatus, that is a grid without a gas-liquid layer. Simple empirical formulas were obtained for the coefficient of dry grids and the existence is pointed out of an optimum thickness for the grid at which will be found the minimum coefficient for local resistance. It is suggested that one reason for the apparent divergence in the determination of the coefficients of resistance by various investigators appears to be the influence of the thickness of the grid, a factor not taken into account by them.

A. S. Ginevskii

Courtesy Referativnyi Zhurnal, USSR

5207. Gegeliya, T. G., Sediment-intercepting channel of an intake dam (in Russian), *Gidrotekh. Stroit.* **27**, 12, 30–32, Dec. 1958.

Low-placed intakes with horizontal entrances are desirable and are used in mountain streams in order to collect the whole discharge, particularly in dry season. This type of intake represents a channel built in a low spillway across the river and covered by a trash rack. The trash rack cannot prevent the inflow of sediments of the size smaller than the trash rack openings into the channel, which limit the use of this type of intake. The author investigated and found that a sediment-intercepting channel built upstream and parallel to the intake channel also in the spillway, designed by him and erected on Bagnari plant, solves the problem.

The sediments from the intercepting channel are diverted downstream of the dam passing first through pipes, then by a tunnel located in the right abutment. This tunnel has connection with upstream water level and has a gate. By opening the gate the tunnel can be washed of sediments which might accumulate on its bottom.

The author presents detailed, almost construction drawings, which supply enough information to build this type of stream intake with sediment-intercepting installation. He also discusses and recommends the type and size of openings for trash racks for both

intake and sediment-intercepting channels based on laboratory investigation and over 8-years' observation on Bagnari and other Caucasian power plants of small size.

The writer's opinion is that this type of intake must be considered as an alternative for the design of developments in similar site conditions. B. S. Browzin, USA

5208. Bashkirov, G. S., Approximate simulation of the scouring at the bottom of a reservoir (in Russian), *Nauchn. Trudi Odessk. In-ta Inzh. Morsk. Flota* no. 13, 121–125, 1957; *Ref. Zh. Mekh.* no. 8, 1958, no. 8761.

The proposed method of approximate simulation (modelling) of the scouring of the bottom of a reservoir is founded on the equation of equilibrium of the particles of soil on the slope of the sides of the reservoir (or basin). This equation, in a slightly more complicated form than that originally suggested by the same author [*Gidrotekhn. Stroo*, no. 10, 30–32, 1952] is, however, still as approximate as many other such suggestions, and does not appear to have any particular advantages compared with them. The flow velocity of the water is determined analytically by the equation for waves of small amplitude for the case of a horizontal bottom, i.e., neglecting any influence of slope of the bottom. No data for correlating the analytical with the experimental data are furnished.

M. A. Dement'ev

Courtesy Referativnyi Zhurnal, USSR

5209. Khachatrian, P. M., The applicability of the postulate of constant specific energy of a flow in the hydraulic analysis of the bottom grid of a mountain reservoir (in Armenian), *Trudi Arm. Nauk-i. In-ta Gidrotekhn. i Melior.* **2**, 75–85, 1957; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 8782.

Results are described of experimental investigations on a model of the bottom grid of a mountain catchment reservoir. The tests were made with a bar grid, either installed on the crown of the weir or placed flush with the bottom. The dimensions of the grid were length 38 cm, width 40 cm (Ist series); and, correspondingly, 30 and 50 cm (IInd series). The discharge volumes for the model were 15.8–32.6 *l*/sec in the Ist series, and 41.5–70 *l*/sec in the IInd series. The experiments concerned the determination of the pressure and velocity distributions in the flow, over the length of the grid. The curves of pressure distribution along the horizontal grid, reproduced in the figures and calculated by the equation

$$0 = h + (\alpha V^2/2_g),$$

(where h and V are depth and mean velocity over the cross section of the flow, along the grid; $\alpha = 1$), indicate that for a grid located on the crest of a weir they deviate somewhat from the hydrostatic law; for a grid placed flush with the bottom, the pressure distribution, excepting the starting and finishing lengths of the grid, practically follows the hydrostatic law. If the curvature of the streamlines is upwardly convex, the pressure is less than the hydrostatic; in the contrary case, it is greater. The curves plotted from the measured pressure values and the absolute values of the velocities, for a grid with $p = s/(s + t) = 0.272$ and 0.358 (where t is the width of one bar of the grid and s is the width of the gap between the bars) and a weir with a wide flow section, can be represented by horizontal lines. These results are the experimental confirmation of the practical admissibility of the postulate of constant, specific energy of a flow along a bottom grid, and a weir with a wide threshold. On this assumption, the author is of the opinion that the diversion of a part of the discharge from the fundamental mass of the flow along the grid does not involve perceptible losses of specific flow energy; and the application of the equation of motion of a liquid of variable mass to the hydraulic analysis of a bottom grid "does not introduce any new factors into the calculation...." V. V. Fandeev

Courtesy Referativnyi Zhurnal, USSR

5210. Petrov, G. A., An open damping device with longitudinal slits in its bottom side (in Russian), *Gidrotekhn. i Melior.* no. 9, 11–16, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6360.

An investigation is carried out regarding the hydraulic calculations for a damper with longitudinal slots in the end of the tank which is sloped in excess of the critical (due to rapid currents or an over-hanging fall). The calculation is based on the author's adoption of the equation of motion of a liquid with variable mass. ["The motion of a liquid with a change of discharge along its route," Moscow-Leningrad, Stroiizdat, 1951.] The horizontal bottom of the damper should be placed at the water level of the diversion canal, or not more than 10–15 cm above that level. The longitudinal bottom slits, according to the preliminary data received, are recommended to be 0.1 to 0.2 m for the width a, while the distance between the axes should not be less than $4a$. An example of the calculation is given. V. V. Fandeev

Courtesy Referativnyi Zhurnal, USSR

5211. Gusein-Zade, M. A., Motion of a liquid in two strata when taking into account local points of junction between them (in Russian), *Trudi Mosk. Neft. In-ta* no. 20, 23–33, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6538.

An investigation is carried out on the motion of a liquid in two strata divided by an impermeable partition which contains separate weakly permeable portions, when a battery of force wells is operating, the wells being of equal yield capacity and located at equal distances from each other, and a battery of identical wells is operating but each one of its wells is connected to only one of the strata. The problem is then examined of the distribution of pressures in the strata and of the possibility of an overflow of liquid from one stratum to the other through the permeable portions of the partition. The problem is solved in an approximate form by division of the strata into separate portions and by utilizing for these portions the known results. Calculations are furnished for concrete examples. Some practical recommendations are put forward.

T. I. Matveenko

Courtesy Referativnyi Zhurnal, USSR

5212. Steinecke, V., and Zehetner, J., Determination of the mean velocity value in a circular tube (in German), *Brennstoff-Wärme-Kraft* **12**, 3, 118–121, Mar. 1960.

5213. Bozoky-Szeszich, K., Investigation of overland flow (in Hungarian), *Hidrológiai Közlöny* **39**, 4, 267–272, Aug. 1959.

Prior to dealing with laws governing the hydraulics of thin-sheet irrigation, those applying to hydraulics of a thin water sheet moving steadily at constant velocity are discussed. Experiments were carried out in a laboratory glass flume using flax stalks as artificial vegetation to attain the required degree of surface roughness. Neglecting minor discrepancies, the relationship obtained for the purely quadratic range of turbulent water movement is in fair agreement with the formula of Bretting derived for the case of high Reynolds numbers and high relative roughness. It could be assumed therefore that Bretting's formula holds well also for low Reynolds numbers and high relative roughness values, which occurred during these experiments.

The ε roughness coefficient, computed by the formula of Colebrook and White from results of measurements on the terrain covered with vegetation, was found to scatter between very wide limits. Investigations have shown the value of ε to vary with water depth and velocity, while being primarily governed by the density of vegetation and the type of soil. Therefore ε cannot be defined as absolute roughness identical with an effective particle size, but as representative particle size depending upon the effects of the terrain, vegetation, water depth and velocity, respectively, as the degree of hydraulic roughness.

From author's summary

5214. Mikhailov, I. G., and Shutilov, V. A., A simple method for observing cavitation in liquids, *Soviet Phys.-Acoustics* **5,** 3, 385–387 (Letters to the editor), Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 376–377, July/Sept. 1959 by Amer. Inst. Phys., New York, N. Y.)

5215. Yalin, S., Significance of dimensional analysis in hydraulic research methods (in German), *Bautechnik* **36,** 8, 306–312, Aug. 1959.

Author presents the π-theorem (without proof) and illustrates its application to hydraulic problems by a number of widely chosen examples. J. Solvey, Australia

Incompressible Flow

(See also Revs. 4996, 5122, 5202, 5203, 5228, 5294, 5297, 5298, 5303, 5353, 5366, 5374, 5444, 5447, 5448, 5459, 5518, 5529, 5534)

5216. Wan, K.-S., A study of similarity transformations for the equations of two-dimensional incompressible viscous fluid flow, AFOSR TN 59–1257 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 537), 21 pp., Dec. 1959.

The investigation is carried out to obtain the possible similarity transformations to a laminar flow equation and the Navier-Stokes equation for two-dimensional unsteady and steady flows in both Cartesian and polar coordinates. As a result, additional similarity transformations are obtained. These transformations include those obtained previously in the boundary-layer theory as special cases.

From author's summary by M. Kawaguti, Japan

5217. Rosen, G., Integration theory for one-dimensional viscous flow, *Physics of Fluids* **2,** 5, 517–520, Sept./Oct. 1959.

The velocity is first eliminated rigorously from the exact equations for mass and momentum conservation which govern unsteady, one-dimensional viscous flow. A class of exact solutions for polytropic processes is then derived and discussed in detail. The general solution for tangent-gas behavior is also presented.

From author's summary by S. Tomotika, Japan

5218. Koskarov, V. P., A precise solution of the equations of hydrodynamics for a viscous incompressible liquid for a laminar flow (in Russian), *Uch. Zap. Kazakhsk. In-ta* **30,** 79–86, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6390.

The following equation is used to express a nonstationary rectilinear-parallel flow of a viscous incompressible liquid between two parallel planes

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} \qquad [1]$$

with boundary conditions

$$u = 0 \quad \text{with } y = 0$$
$$u = u_0 \cos nt \text{ with } y = 1 \qquad [2]$$

A particular solution of Eq. [1] is evolved using Fourier's method, which satisfied boundary conditions [2]. The question regarding the satisfying of the critical condition is not touched on. The solution of the given problem, satisfying however not only the boundary but the initial conditions as well, is well known (see for instance, N. A. Slezkin, "The dynamics of a viscous incompressible liquid," Moscow, Gostekhizdat, p. 322. The solution evolved by the author is obtained from the general in asymptotic form.) In paragraph 3 of the paper the equation for the temperature

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial y^2} + \frac{\nu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2$$

is also solved by Fourier's method without investigation of concrete boundary conditions for the temperature and consideration of the initial conditions. N. A. Slezkin

Courtesy Referativnyi Zhurnal, USSR

5219. Sakadi, Z., Stationary motion of viscous fluid around a rotating solid sphere, *Mem. Fac. Engng., Nagoya Univ.* **10,** 1, 42–45 (Research Reports), May 1958.

Reviewer believes "non-Newtonian" should have replaced "viscous" in the title, as author includes a constant multiple of $\sum_k \sigma_{ik}\,\sigma_{jk}$ in the stress tensor, where σ_{ij} is the rate of strain tensor $(\partial u_i/\partial x_j) + (\partial u_j/\partial x_i)$. Author assumes small constant angular velocity ω and finds, by straightforward perturbation, the order ω^3 effect of the nonlinear terms on velocity and pressure. The only physical result is the negative one that the moment on the sphere is the same as in the linear case.

L. A. Segel, USA

5220. Boley, B. A., and Friedman, M. B., On the viscous flow around the leading edge of a flat plate, *J. Aero/Space Sci.* **26,** 7, 453–454 (Readers' Forum), July 1959.

An assumed expression for the stream function containing one arbitrary parameter is inserted into the Navier-Stokes equations. The error is multiplied with a suitable weight function and integrated over the flow field. By suitable choice of the parameter this integral is made zero. The expression thus obtained can be considered as an approximation to the real flow field, if the initial expression has been chosen judiciously.

K. G. Guderley, USA

5221. Ripp, M. G., The coefficient of kinetic energy of a flow (in Russian), *Izv. Dnepropetr. Gorn. In-ta* **31,** 41–44, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6300.

By means of an investigation of the expression for a diagram of the distribution of the velocities of a flow in a wide rectangular tube with an indicator of degree $1/m$ the author is able to derive for it an expression for the coefficient of the kinetic energy of the flow

$$K = \frac{(m+1)^3}{m^2(m+3)}.$$

Then the author proceeds to obtain an expression for K through the relation of the maximum velocity of the flow to the mean flow. The obtained formulas can only be exactly applied to tubes of wide rectangular section. A. M. Latyshenkov

Courtesy Referativnyi Zhurnal, USSR

5222. James, W., and Silberman, E., Two-phase flow studies in horizontal pipes with special reference to bubbly mixtures, Univ. Minn., St. Anthony Falls Hydraulic Lab. Tech. Pap. no. 26, Series B, 63 pp., Sept. 1958.

An investigation has been made of the flow of bubbly mixtures in horizontal pipes, together with some related work on other flow patterns. Pressure drop is calculated through the use of a conventional friction factor. In the bubble-flow regime, it is found that the friction factor is approximately equal to or slightly greater than the friction factor for liquid flowing alone in the pipe. The bubbles move at nearly the mean velocity of the liquid while their size is inversely proportional to the liquid velocity and directly proportional to the square root of the pipe diameter.

The use of a friction factor for calculating pressure drop for other than bubble flow may also be useful, but more study is necessary to determine friction factors.

From authors' summary by S. R. Faris, USA

5223. Gordier, R. L., Studies on fluid jets discharging normally into moving liquid, Univ. Minn., St. Anthony Falls Hydraulic Lab. Tech. Pap. no. 28, Series B, 48 pp., Aug. 1959.

Results of an experimental water-tunnel study of penetration of water jets and air-water mixtures from a side orifice into a 4- to 10-ft/sec stream are presented. Author verifies the NACA jet penetration correlations and makes extension of same for jet-main stream velocity ratios from six to fifteen.

R. H. Page, USA

5224. Donald, M. B., and Singer, H., Entrainment in turbulent fluid jets, *Trans. Inst. Chem. Engrs.* **37,** 5, 255–267, Oct. 1959.

A jet of one fluid enters another fluid at rest at infinity. Experimental data are for water-water, air-air, and hydrogen-air. Jet angles were measured by photographing the cone seen when dye or smoke is introduced into the primary fluid. Authors note that the angle thus measured is not unique, but depends upon the dye and the exposure of the photograph. For the water jets, the total flow within the cone was measured by collecting it in a tube, as in a jet pump. The measurements had to be extrapolated to zero head in the tank containing the secondary fluid, and, as noted in the discussion following the paper, this is not completely satisfactory. Approximate formulas, based on momentum balances and on the observation that the secondary fluid enters the cone nearly at right angles to the jet axis, are given to calculate the entrained flow. The cone angle is roughly correlated with Reynolds number.

Reviewer feels that more experimental work, including velocity traverses, should be done so as to permit rigorous definition of cone angle, and proper formulation of the momentum balances.

J. F. Davidson, England

5225. Miller, D. R., and Comings, E. W., Force-momentum fields in a dual-jet flow, *J. Fluid Mech.* **7,** 2, 237–256, Feb. 1960.

The jets were effectively two-dimensional and issued normal to a wall at a speed of about 70 fps 6 jet widths apart into air at rest. The measurements include traverses of mean flow speed and direction, mean static pressure and the normal turbulent stress taken over both the initial region where the jets were separate but converging and the region further downstream where they coalesce. The results are compared with the results of earlier measurements on a single jet. Of particular interest is the large suction generated initially between the jets and the associated lateral pressure gradients and rapid convergence of the jets, the subsequent pressure and free stagnation point on the plane of symmetry, and the strong similarity between the ultimate development of the combined jet and that of a single jet. Reviewer believes that the results are a valuable addition to existing data on mixing processes of turbulent jets.

A. D. Young, England

5226. Kashkarov, V. P., On the jet motion of a viscous liquid in a conical diffusor (in Serbian), *Izv. Akad. Nauk KazSSR. Ser. Matem. i Mekhan.* no. 6(10), 20–26, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6400.

Without reference to the article by the abstractor [N. A. Slezkin, *Uch. Zap. MGU* no. 11, 1934; *Prikl. Mat. Mekh.* **18,** 6, p. 764, 1954], a fresh approach is made to the investigation of the case of a steady axially symmetrical flow, for which the full differential equations of motion are reducible to Riccati's equation. The solution of this equation, with the aid of hypergeometrical functions, is examined in an article by V. I. Yatseev [*Zh. Eksp. Teor. Fiz.* no. 11, 1950] and in L. I. Sedov's book ["Methods of similarity and dimensions in mechanics," Gostekhizdat, 1951]. The author investigates the special case in which the solution of Riccati's equation is represented through elementary functions. One constant in this solution is chosen from the condition of the conversion to zero value of the velocity along the normal to the walls of the diffusor. As the pressure on the cone is not constant, it is not possible to agree with the author's contribution that the motion studied is of a jet-type. The solution is also examined of an energy equation in relation to the temperature. This solution for the case of flow of a viscous liquid investigated by the author is also presented through elementary functions. Graphs are given for the lines of current and the isotherms.

N. A. Slezkin

Courtesy Referativnyi Zhurnal, USSR

5227. Taub, A. H., On circulation in relativistic hydrodynamics (in English), *Arch. Rational Mech. Anal.* **3,** 4, 312–324, Aug. 1959.

It is shown that the relativistic analog of the circulation in classical hydrodynamics is the integral

$$C = \int \left(1 + \frac{i}{c^2}\right) U_\alpha \, dx^\alpha,$$

where i is the specific enthalpy of the fluid, U_α are the covariant components of the four velocity components of the fluid and the integral is taken around a closed curve traveling with the fluid. This integral is similar to an integral given by Lichnerowicz, but differs in the factor multiplying U_α in the integrand.

The necessary and sufficient conditions for C to vanish are shown to be that the flow be irrotational and isentropic. The necessary and sufficient condition for C to be a constant of the motion is that the pressure be a function of the density alone at every point in space-time occupied by the fluid. This condition is shown to be violated when a shock is present. Results for similar integrals taken around vortex lines are also obtained. The relations between these results and Bernoulli's theorems are discussed.

From author's summary

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 4996, 5222, 5257, 5261, 5262, 5271, 5281, 5282, 5283, 5284, 5285, 5286, 5293, 5302, 5313, 5345, 5346, 5362, 5375, 5386, 5421, 5437, 5445, 5450, 5486, 5500, 5509, 5520)

Book—5228. Loitsianskii, L. G., Mechanics of liquids and gases [Mekhanika Zhidkosti i Gaza], Moskva, Gosudarstvennoe Izdatel'stvo Fiziko-Matematicheskoi Literatury, 1959, 784 pp. 16 r 50 k.

Lev Gerasimovich Loitsianskii, professor of fluid mechanics in Leningrad, is well known in the USSR by his books "Theoretical mechanics:" (two volumes), "Boundary layer," "Mechanics of liquids and gases" and numerous articles. His present book touches practically all the problems of modern fluid mechancis and, in that respect, is unique. It should, however, be mentioned that none of its three issues has been approved by the Ministry of Higher Education of the USSR as a textbook, and the reasons seem to be evident.

The planning of the material and, in some cases, the manner of its presentation could be more satisfactory. The first 40 pages deal with the history of hydro- and aerodynamics in Russia and the USSR. Then he dedicates some 36 pages to Euler and Lagrange methods; to stream-tube and vortex tube theories; to Helmholtz and Kelvin theorems; to circulation and applications of tensor calculus to the solution of kinematic problems. And only after that, namely on pages 80–83, does he proceed to the physical properties of liquids and gases.

The rest of the book is divided as follows: pages 127–196, gasdynamics; pages 197–311, basic concepts of classical incompressible hydrodynamics; 312–365, again gasdynamics; pages 366–430, problems of noncompressible aerodynamics; pages 431–446, compressibility effects; pages 459–571, the dynamics of incompressi-

ble viscous liquids; pages 572–697, the theory of turbulence; pages 698–773, the dynamics of viscid gases.

The book, although methodically not sound enough, can be recommended as a rich, important and interesting source of information. It certainly deserves to be published in English.

G. A. Tokaty, USA

5229. Morioka, S., High subsonic flow past a wedge in a two-dimensional wind tunnel at its choked state, *J. Phys. Soc. Japan* **14,** 8, 1098–1101, Aug. 1959.

Paper briefly describes an approximate solution of the flow field past a symmetric double wedge profile in a Tricomi gas using Vincenti and Wagoner's relaxation procedure [AMR **6**(1953), Rev. 3808] in the subsonic region and the method of characteristics in the supersonic region. Computation of the pressure coefficient is made for a range of values of the transonic similarity parameter and good agreement is shown with Marschner's analytical solution [AMR **9**(1956), Rev. 2676]. Author also estimates the choking Mach number as a function of airfoil thickness/tunnel width and concludes that its determination is "a delicate problem to the transonic approximation theory." Reviewer agrees. Appendix treats the limiting case of the wedge in a sonic free stream; numerical results show fair agreement with those of Guderley and Yoshihara [AMR **5**(1952), Rev. 3299].

J. B. Helliwell, Scotland

5230. Pivko, S., Effectiveness of propellers at high speeds—a simplified analysis of the operation and effectiveness of propellers and helicopter rotors at transonic speeds, *Aircr. Engng.* **31,** 370, 360–364, Dec. 1959.

Author's summary appropriately states that the operating conditions in both subsonic and supersonic region are separately considered and the performance is predicted approximately by strip theory. Reviewer feels that the analysis is not applicable to transonic speeds and thus incapable of predicting the lower limit of the performance in transonic flow. Nevertheless, result indicates low efficiency of propeller beyond high subsonic speeds.

W.-H. Chu, USA

5231. Harrison, W. P., Jr., Computer solution techniques for two-dimensional supersonic flow problems, *J. Aero/Space Sci.* **27,** 4, 315–316 (Readers' Forum), Apr. 1960.

Author considers flow solution by the well-known shock-expansion method.

Mach number behind shock at leading edge of airfoil is related to flow-turning angle by a known cubic equation. Author prefers explicit solution to iterative solutions of this equation on the grounds that former is "more accurate and less time-consuming," but offers no supporting evidence.

Local Mach number at a downstream point is related to local airfoil surface slope by the Prandtl-Meyer equation. To invert this equation, author recommends Newton's well-known method.

A. H. Armstrong, England

5232. Bird, G. A., A simple numerical solution of the supersonic blunt-body problem for real gases, *J. Aero/Space Sci.* **27,** 2, 151–152 (Readers' Forum), Feb. 1960.

It is shown that a satisfactory hand solution of surprising accuracy may be obtained from a step-by-step method which makes use of only elementary forms of the equations of motion and which may, therefore, be based on realistic assumptions about the thermodynamic processes.

From author's summary

5233. Grant, F. C., Measured and predicted section wave drag coefficients at a Mach number of 1.6 for a delta wing with two airfoil sections, NASA TN D-11, 41 pp., Sept. 1959.

Experimental and theoretical aerodynamic data are presented for two delta wings—one with an NACA 65A006 airfoil section and the other with a 6-percent thick section and the same longitudinal cross-sectional area distribution as a Sears-Haack optimum body of revolution for a given length and volume.

When compared with linearized theory, the experimental results show a much smaller variation in spanwise wave drag coefficients for the Sears-Haack wing. The linear theory prediction that the 65A was the better airfoil was shown experimentally, although the sectional drag coefficient was in error by 17%.

E. K. Parks, USA

5234. Wegener, P. P., Supersonic nozzle flow with a reacting gas mixture, *Physics of Fluids* **2,** 3, 264–275, May/June 1959.

Investigation of the stationary supersonic nozzle flow of a reacting gas mixture of nitrogen tetroxide and dioxide carried at low concentration in nitrogen. Supply conditions and nozzle geometry made it possible to produce flows either in chemical equilibrium or in states between this and frozen flow. Flow could be fully determined from pressure and area measurements and, by applying an equation for the reaction mechanism, rate constants of recombination could be found. Results of these measurements agreed with those obtained from independent optical measurements, and third-order rate constant for recombination was found to be 3×10^{14} cm^6 mole^{-2} sec^{-1} for $210 < T < 330$ °K. Experiments with stationary oblique shocks led to a determination of the dissociation rate constant.

From author's summary by R. A. Gross, USA

5235. Ting, L., On the integral of moment of pressure in supersonic flow, AFSOR TN 59-358 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 449; ASTIA AD 213 684), 14 pp., May 1959.

The integral of the moment of the disturbance pressure along the line of the interaction of a Mach plane with the cylindrical surface, whose generator is parallel to the undisturbed stream, is shown to be related to the integral of the moment of the prescribed normal velocity along the same line. Its applications in problems of planar systems and wing-body combinations at supersonic speed are presented.

From author's summary by A. E. Bryson, Jr., USA

5236. Kobayakawa, S., and Ting, L., Interference of body and trailing edge vortex sheet in supersonic flow, AFOSR TN 59-453 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 516; ASTIA AD 215 028), 27 pp., May 1959.

Ting's generalized integral relationship [AMR **12**(1959), Rev 4612] in linearized supersonic flow past cylindrical surfaces is extended to include cylindrical vortex sheets. The relationship is then applied to find an approximate pressure distribution on the body of a wing-body combination in the domain of influence of the wing trailing edge.

A. E. Bryson, Jr., USA

5237. Coupry, G., Three-dimensional quasi-static aerodynamic coefficients in supersonic flow (in French), ONERA Pub. 69, 49–56, Mar./Apr. 1959.

Expressions are derived for the in-phase and out-of-phase components of lift and pitching moment on three-dimensional wings, in supersonic flow, which undergo harmonic oscillations in pitch and and in "vertical" translation. The method of analysis employs representation in series, as a function of the reduced frequency, and retains first-order terms to obtain quasi-static aerodynamic derivatives from steady-state coefficients.

For rectangular wings the results are identical with those of Watkins [AMR **6**(1953), Rev. 212], and for delta wings there is good agreement with Watkins and Berman [AMR **7**(1954), Rev. 2247] at free-stream Mach numbers exceeding 1.2. Formulas are quoted also for swept wings with streamwise tips.

S. Kirkby, England

5238. Anliker, M., A numerical method of evaluating the velocity potential and the minimum drag warping of arbitrary supersonic wings (in English), *ZAMP* **10,** 1, 1–14, Jan. 1959.

In general it is not possible to give closed-form analytical expressions for aerodynamic influence coefficients. Therefore numerical methods have to be applied. Analogous to investigations on a digital computer program for the evaluation of oscillatory aerodynamic forces on supersonic wings by means of velocity potential influence coefficients author has computed the steady-state pressure drag due to the warping of thin wings. Velocity potential influence coefficients are based on linearized potential flow theory neglecting wing-body interference. The disturbed flow region is subdivided by a "Mach box grid" as proposed by Li to approximate the velocity potential. The unknown warping which minimizes the drag due to lift can be approximated by a power series in the stream- and spanwise coordinates. In the case of subsonic leading edge the coefficients for the leading-edge suction have to be supplemented. Minimum problem is solved by evaluating the coefficients of the power series. Given procedure is valid for wings with subsonic-, sonic- and supersonic leading edge and in general for thin wings of which the leading and trailing edges have the form of piecewise steady curves.

Comparison of harmonic and numerical method is shown for a swept wing with side edges for two Mach numbers corresponding to a sonic and supersonic leading-edge condition. The results illustrate the adequacy of the approximation of the optimum warping by the first ten terms of a power series in the nondimensional stream- and spanwise coordinates.

G. A. Altmann, Germany

5239. Van Dyke, M. D., and Gordon, Helen D., Supersonic flow past a family of blunt axisymmetric bodies, NASA TR R-1, 25 pp., 1959.

Some 100 numerical computations have been carried out for unyawed bodies of revolution with detached bow waves. The gas is assumed perfect with $\gamma = 5/3$, 7/5, or 1. Free-stream Mach numbers are taken as 1.2, 1.5, 2, 3, 4, 6, 10 and ∞. The results are summarized with emphasis on the sphere and paraboloid.

From authors' summary

5240. Mueller, J. N., Close, W. H., and Henderson, A., Jr., An investigation of induced-pressure phenomena on axially symmetric, flow-alined, cylindrical models equipped with different nose shapes at free-stream Mach numbers from 15.6 to 21 in helium, NASA TN D-373, 48 pp., May 1960.

Induced-pressure-distribution studies were made in a 2-inch helium tunnel and the Langley 11-inch hypersonic tunnel on six nose shapes: a hemisphere, a 45° included-angle cone, a 90° included-angle cone, a hemispherically blunted 45° included-angle cone, a hemisphere modified by a 90° included-angle conical tip, and a flat configuration. Pressures were measured on the models from 0 to 50 model diameters from the nose-cylinder juncture. The effects of Reynolds numbers were determined in the range from 0.062 to 0.75×10^6. Comparisons were made of data obtained in a conical, or Mach number gradient, nozzle with data obtained in a uniform-flow nozzle (no Mach number gradient).

From authors' summary

5241. Nagamatsu, H. T., Geiger, R. E., and Sheer, R. E., Jr., Real gas effects in flow over blunt bodies at hypersonic speeds, *J. Aero/Space Sci.* **27,** 4, 241-251, Apr. 1960.

A hypersonic shock tunnel has been developed to investigate the aerodynamic characteristics of flow over bodies at conditions comparable to those encountered by ballistic missiles and satellites re-entering the atmosphere. Some results for a shock velocity of over 50,000 fps in the shock-tube portion of the facility are presented. Static pressure investigations were made in the nozzle to determine the flow condition and the expansion process.

The results of the investigation of representative blunt bodies at hypersonic Mach numbers and nozzle stagnation temperatures up to approximately 6000°K are presented. These include body pressure distributions, shock-wave shapes, detachment distances, and photographs of the luminous gas region in the shock layer. It is seen that the shock detachment distance is smaller at higher stagnation temperatures due to the real gas effects. For the hemisphere the pressure distribution was less than that predicted by the modified Newtonian theory for all stagnation temperatures. For a 50° cone-hemisphere the pressure distribution and the shock detachment distance were appreciably affected by the real gas effects.

The observed shock-wave shape and the approximate boundary layer on a flat plate are compared with the analytical prediction. Some preliminary results for the detached shock wave produced by a blunt two-dimensional body in a low density flow at a Mach number of 19.6 are presented.

From authors' summary by W. F. Davis, USA

5242. Cheng, H. K., On the structure of vortical layers in supersonic and hypersonic flows, *J. Aero/Space Sci.* **27,** 2, 155-156 (Readers' Forum), Feb. 1960.

The strong vorticity layer characterized by large entropy gradients close to the surface of a slightly yawed cone in a supersonic flow is analytically investigated. An example of the entropy field in the vortical layer for 30° cone at a $M_\infty = 4.59$ and angles of yaw of 2° and 5° is shown.

S. Eskinazi, USA

5243. Hamaker, F. M., Numerical solution of the flow of a perfect gas over a circular cylinder at infinite Mach number, NASA Memo 2-25-59A, 33 pp., Mar. 1959.

A solution for the two-dimensional flow of an inviscid perfect gas over a circular cylinder at infinite Mach number is obtained by numerical methods of analysis. Nonisentropic conditions of curved shock waves and vorticity are included in the solution. The analysis is divided into two distinct regions, the subsonic region which is analyzed by the relaxation method of Southwell and the supersonic region which is treated by the method of characteristics. Both these methods of analysis are inapplicable on the sonic line, which is therefore considered separately. The shapes of the sonic line and the shock wave are obtained by iteration techniques.

The striking result of the solution is the strong curvature of the sonic line and of the other lines of constant Mach number. Because of this the influence of the supersonic flow on the sonic line is negligible. On comparison with Newtonian flow methods, it is found that the approximate methods show a larger variation of surface pressure than is given by the present solution.

From author s summary by R. E. Bolz, USA

5244. Morgan, P. G., High speed flow through perforated plates, *J. Roy. Aero. Soc.* **64,** 590, 103-105 (Tech. Notes), Feb. 1960.

5245. Heyman, R. J., Mach-line determination for air in dissociation equilibrium, *J. Aero/Space Sci.* **27,** 4, 311-312 (Readers' Forum), Apr. 1960.

The density ratio across an oblique shock is written for a gas in dissociation equilibrium. The limiting condition of zero change in flow direction then gives the relationship between Mach angle and Mach number. Example calculations are included for air.

T. C. Adamson, Jr., USA

5246. Losev, S. A., and Generalov, N. A., Measuring the temperature of a gas downstream from a shock wave, *Instruments and Experimental Techniques* no. 3, 454-456, 509, Apr. 1960. (Translation of *Pribory i Tekhnika Eksperimenta, USSR* no. 3, 108-109, May/June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A technique has been devised for measuring the temperature of a gas on the basis of the emitting and absorbing powers of the sodium D lines and has been used to measure high temperatures de-

veloped in a gas aft of a strong shock wave (under laboratory conditions). For absorption observations, the intense emission from a pulsed IPS-500 tube was used. Temperatures ranging from 4000° to 5000° were measured, with an error of ±100–200°K.
From authors' summary

5247. Ribner, H. S., The sound generated by interaction of a single vortex with a shock wave, AFOSR TN 59-1166 (Univ. Toronto, Inst. Aerophys. Rep. 61), 20 pp., June 1959.

Using the Fourier method, author analyzes vortex into shear waves, using known results for interaction of simple shear waves and shock. A quasi-cylindrical sound wave results in which the peak pressure attenuates inversely as the square root of radial distance, and varies smoothly from compression at one shock intersection to rarefaction at the other. Comparison is made with results of shock-tube investigation. N. Curle, England

5248. Ehlers, F. E., and Shoemaker, E. M., A three-dimensional linearized analysis of the forces exerted on a rigid wing by a shock wave, *J. Aero/Space Sci.* **27,** 4, 257–260, Apr. 1960.

The pressure distribution on a moving flat plate induced by an acoustic shock front striking the edge of the plate obliquely has been found in terms of the two-dimensional solution of the authors [title source **26,** 2, 75–80, Feb. 1959; AMR **12**(1959), Rev. 4003].
From authors' summary by D. C. Leigh, USA

5249. Galin, G. Ya., A theory of shock waves, *Soviet Phys.-Doklady* **4,** 4, 757–760, Feb. 1960. (Translation of *Dokladi Akad, Nauk SSSR (N.S.)* **127,** 1, 55–58, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Contained herein is an investigation of the conditions necessary for the existence of continuous solutions to the system of equations which govern the motion through a steady shock (viscosity and heat conduction included). The analysis assumes an arbitrary equation of state and has application to shock waves in a solid as well as in gases and liquids.

The analysis is carried out by investigating the character of the singular points of the governing equations in the P-V plane along with the behavior of the shock adiabatic in this plane. It is the behavior of this adiabatic—its path in the P-V plane—which provides the necessary and sufficient conditions for the existence of continuous solutions. It is shown here that crossing of the straight line which joins the shock endpoints (P_0, V_0), (P_1, V_1) in the P-V plane by this adiabatic rules out the possibility of the existence of continuous solutions.

The question of stability of such flows is not considered here. Also the paper is presented in such a manner that for those not intimately concerned with this problem the reasoning may not always be obvious. This work will find use only among those interested in the theoretical or analytical investigation of the shock structure.
K. A. Faymon, USA

5250. Landsbaum, E. M., Contour nozzles, *ARS J.* **30,** 3, 244–250, Mar. 1960.

A number of contour nozzles for an ideal gas with $\gamma = 1.22$ are presented. The variation of gamma is considered. The design is based upon the assumption of a radial flow section in the initial divergent section which is turned to uniform axially directed flow at the exit. For each specified exit Mach number, about 95% of the maximum expansion angles were used. The contours obtained were cut back in order to yield nozzles of various exit areas. The surface area of the divergent section, thrust coefficient and length of these cutback nozzles are compared with those properties of 15-deg half-angle conical nozzles with the same exit area. Simple heat flux calculations for some of the designs are also presented. These designs result in moderate savings in length, surface area and heat flux over a 15-deg nozzle with the same thrust coefficient. Greater savings are possible at the expense of reducing the thrust coefficient. From author's summary

5251. Snyder, W. T., Nonisentropic nozzle flow, *ARS J.* **30,** 3, 270–271 (Tech. Notes), Mar. 1960.

5252. Guderley, G., On Rao's method for the computation of exhaust nozzles (in English), *Z. Flugwiss.* **7,** 12, 345–350, Dec. 1959.

Author considers in detail certain physical ideas underlying Rao's formulation of problem [AMR **11**(1958), Rev. 5051]. Analysis is extended to include axisymmetric flows where entropy varies from streamline to streamline. G. Power, England

5253. Kennet, H., Prandtl-Meyer expansion in equilibrium air, *ARS J.* **30,** 3, 288–289 (Tech. Notes), Mar. 1960.

Boundary Layer

(See also Revs. 5216, 5220, 5224, 5228, 5274, 5275, 5283, 5328, 5344, 5370, 5374, 5384, 5386, 5389, 5401, 5448, 5451, 5521)

5254. Sun, E. Y. Ch., A compilation of coordinate transformations applied to the boundary-layer equations for laminar flows, Dtsch. Versuchsanstalt Luftfahrt, Ber. 121, 42 pp., Mar. 1960.

This report consists of a compilation of the most frequently used coordinate transformations for the boundary-layer equations. Five basic transformations, namely, the generalized similarity transformation, the v. Mises, the Crocco, the Mangler and the Howarth transformations, are deduced and described in detail. In addition to these five basic transformations, 14 further transformations are included which may be treated as generalizations and combinations of the five basic ones. From author's summary

5255. Kline, S. J., Lisin, A. V., and Waitman, B. A., Preliminary experimental investigation of effect of free-stream turbulence on turbulent boundary-layer growth, NASA TN D-368, 60 pp., Mar. 1960.

The results of a preliminary experimental investigation of the effect of free-stream turbulence on the characteristics of the turbulent boundary layer on a flat plate are presented. The normally employed correlations for the turbulent boundary layer on a plate are, in effect, a limiting law for low turbulence in the free stream. However, when the free-stream turbulence is equal to or greater than the self-generated turbulence of the shear layer, considerable alterations in the boundary-layer characteristics occur. Such altered boundary layers do not conform to the "universal" velocity profiles in the form of the law of the wall or the law of the wake. A straight-line portion of the layer on a semilogarithmic plot still exists but its slope and location are altered and are shown to depend upon the imposed free-stream fluctuation intensity.
From authors' summary

5256. Mager, A., and Goldstein, A. W., On maximum pressure rise with turbulent boundary layer, *J. Aero/Space Sci.* **27,** 3, 234–235 (Readers' Forum), Mar. 1960.

5257. Pearcey, H. H., Some effects of shock-induced separation of turbulent boundary layers in transonic flow past aerofoils, Aero. Res. Counc. Lond., Rep. Mem. 3108, 61 pp., 1959.

5258. Leadon, B. M., and Bartle, E. R., Pitot-probe measurement of local skin friction reduction due to transpiration in a low-speed, turbulent boundary layer, *J. Aero/Space Sci.* **27,** 3, 235–236 (Readers' Forum), Mar. 1960.

5259. Arthur, P. D., and Williams, J. G., III, Maximum turbulent boundary layer heating rates on a hemispherical nose, *ARS J.* **30**, 2, 207–208 (Tech. Notes), Feb. 1960.

Authors consider the expression given by Van Driest for the turbulent boundary-layer heat-transfer rate in the close vicinity of the stagnation point in hypersonic flow. They determine the maximum of this expression as a function of the distance from the stagnation point, assuming an isentropic external flow and a "power law" viscosity-temperature dependence. This maximum occurs at a 37 deg angle for sufficiently general cases. Using this value, authors give the formula and the diagram of the ratio of maximum turbulent heating rate to maximum laminar heating rate as a function of the Reynolds number based upon the external velocity and the stagnation point viscosity. It is shown that for $Re_{s2} > 3 \times 10^4$, this ratio exceeds several times unity.

S. Savulescu, Roumania

5260. Braun, W. H., Turbulent boundary layer on a yawed cone in a supersonic stream, NASA TR R-7, 16 pp., 1959.

See AMR **11**(1958), Rev. 3660.

5261. Demetriades, A., An experiment on the stability of hypersonic laminar boundary layers, *J. Fluid Mech.* **7**, 3, 385–396, Mar. 1960.

Paper describes investigation of the laminar boundary layer on a flat plate at zero incidence in a hypersonic stream ($M = 5.8$). Hypersonic stability of the boundary layer was investigated using a hot-wire anemometer to determine the ranges in which small disturbances damp or amplify. Natural fluctuations were measured at constant y/s for varying x. Maximum amplitudes were observed at various frequencies. These maxima were correlated to give a line of maximum amplification which corresponded to the upper neutral branch of the boundary layer stability diagram. It was not possible to detect a lower neutral branch from natural fluctuations. Failure to detect lower branch with natural fluctuations is believed due to free-stream turbulence (0.4%). Artificial fluctuations produced by a siren plate permitted detection of both the upper and lower neutral branches of the stability diagram. Both branches were of similar shape as those previously obtained at lower M numbers. As M increases, separation of the two branches decreases. Amplification rates were observed to be lower than those observed at lower speeds.

J. G. Knudsen, USA

5262. Casaccio, A., First-order solution to the compressible laminar boundary layer in slip flow, *J. Aero/Space Sci.* **27**, 4, 319–320 (Readers' Forum), Apr. 1960.

Author observes that in slip flow for the first-order approximation, the boundary-layer equations of continuum flow theory (continuity, momentum, energy) are applicable with boundary conditions suitably modified. The effect of transverse curvature on the boundary layer is neglected and the Prandtl number has been assumed constant. Author uses a suitable transformation, which combines Stewartson and Mangler-type variables, and applies the method of the perturbations. The solutions of zero-order system, already obtained by Stewartson and solved by Cohen and Reshotko, and those of first-order system are given and some particular cases are considered.

G. Sestini, Italy

5263. Stainback, P. C., An experimental investigation at a Mach number of 4.95 of flow in the vicinity of a 90° interior corner aligned with the free-stream velocity, NASA TN D-184, 30 pp., Feb. 1960.

An investigation was made to determine the effects of the shock-boundary-layer interaction on the static pressure and heat-transfer rate of an interior corner. The investigation was made at a nominal Mach number of 4.95 and a stagnation temperature of 400 F. The nominal Reynolds number for the heat-transfer investigation ranged from 1.95×10^6 to 74.17×10^6 per foot, and for the pressure tests, from 15.19×10^6 to 74.17×10^6 per foot. The results of the investigation indicate that the static pressure and the heat-transfer rate in the vicinity of the corner are greater than the corresponding pressure and heat-transfer rate on a flat plate for the same free-stream conditions.

From author's summary

5264. Ferri, A., The influence of the shock curvature on the behavior of hypersonic boundary layer, AFOSR TN 60-301 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech., PIBAL Rep. no. 542), 40 pp., Feb. 1960.

For moderate values of Reynolds numbers the entropy gradients in the flow field affect the boundary layer in the region far from the nose. These effects are important for heat transfer, especially for a turbulent boundary layer. For moderate values of Reynolds numbers, good results can be obtained by analyzing the boundary layer with correct local stagnation conditions and by neglecting the effect of velocity gradients outside the boundary layer. For lower Reynolds numbers, boundary-layer-type analysis can still be used; however, the effects of velocity gradients must be taken into account in stating the boundary conditions. The effect of vorticity in this case appears to be important.

From author's summary

5265. Hama, F. R., Preliminary studies on boundary-layer transition caused by a thin transverse wire floating from surface, AFOSR TN 60-505 (Inst. Fluid Dynam. Appl. Math., Univ. Maryland TN BN-208), 26 pp., Apr. 1960.

It is found that a thin wire, which is incapable of tripping the flow when it is attached to the surface, can cause transition if it is raised from the surface. A rough criterion of provoking transition at the wire is about 200–300 for the Reynolds number based upon the velocity at the top of the wire and the distance of the top of the wire from the surface, although it depends on the combination of the wire diameter and the raised distance from the surface. This criterion is approximately the same as that for the conventional trip wire attached to the surface. But a possible merit as a tripping device is that a thick wire is not required to block the entire height. The Reynolds number based upon the velocity at the top and the wire diameter can be as small as 75 to trip the flow at the wire.

Important mechanics involved in this arrangement is the following: the flow underneath the wire tends to separate from the surface immediately behind the wire and to break up three-dimensionally, resulting in the formation of longitudinal vortices. Transition is provoked by the coupling between the longitudinal vortices and the two-dimensional vortices formed behind the wire.

From author's summary

5266. Boltz, F. W., Kenyon, G. C., and Allen, C. Q., The boundary-layer transition characteristics of two bodies of revolution, a flat plate, and an unswept wing, in a low-turbulence wind tunnel, NASA TN D-309, 45 pp., Apr. 1960.

An investigation was conducted in the Ames 12-ft low-turbulence pressure tunnel to determine the boundary-layer transition characteristics of two bodies of revolution (fineness ratios 7.5 and 9.0), a flat plate, and an unswept wing (NACA 64_2A015 section) at subsonic speeds. Included in the investigation was a survey of the tunnel turbulence and sound levels using a hot-wire anemometer and a condenser microphone. In all cases it was found that the pressure distribution was a primary factor in determining the level of transition Reynolds number. Adverse effects of increasing Mach number on the transition Reynolds numbers obtained at the lower speeds were found to be attributable to changes in both the frequency and intensity of sound waves in the tunnel.

From authors' summary

5267. Stetson, K. F., Boundary-layer transition on blunt bodies with highly cooled boundary layers, *J. Aero/Space Sci.* **27**, 2, 81–91, Feb. 1960.

Boundary-layer transition investigations have been made on optically polished pyrex hemisphere-cylinder and ellipse-cylinder models with stagnation-to-wall enthalpy ratios between 4.5 and 30.... The shock-tube experiments indicated that a characteristic feature of transition of a highly cooled boundary layer on a hemisphere was the simultaneous occurrence of transition over the entire supersonic portion of the hemisphere. This implies that transition first occurred in the sonic region. The transition Reynolds number (based on local fluid properties at the outer edge of the boundary layer and the momentum thickness) in the sonic region increased from about 225 to 325 as the stagnation-to-wall enthalpy ratio increased from about 9.5 to 29.5. Transition occurred along the cylindrical portion of the hemisphere-cylinder model at a nearly constant momentum thickness Reynolds number, increasing from about 400 to 625 as the stagnation-to-wall enthalpy ratio increased from about 9.5 to 29.5.... Transition Reynolds number did not vary significantly with boundary-layer cooling in this cooling range, but transition always occurred at a low Reynolds number (between about 350,000 and 750,000 based on local external properties and a distance along the body surface from the stagnation point).

From author's summary by E. R. G. Eckert, USA

5268. Lochtenberg, B. H., Transition in a separated laminar boundary layer, *J. Aero/Space Sci.* **27**, 2, 92–96, Feb. 1960.

Transition to turbulence was studied in a separated laminar boundary layer on a flat plate 24 in. long and 1/4 in. thick. Steps with a height of 1/8 to 1/2 in. were provided at a distance of 4 to 8.4 in. from the leading edge. The tunnel velocity was 0.05%. Transition was observed through a hot-wire anemometer. The author concludes that transition was always initiated by Tollmien-Schlichting waves. Two types of transition were observed. In one type, bursts suddenly appeared in the wavy flow. The other type consists of amplification, distortion, and breaking up of the waves. Which type of transition occurs depends on the value of the following parameter: boundary-layer displacement thickness times step height times free-stream velocity squared divided by kinematic velocity squared. The burst type has been observed for values of this parameter larger than 4.2×10^6. The separated laminar boundary layer becomes unstable and develops waves when the critical Reynolds number based on boundary-layer displacement thickness at the step location exceeds a value of 350. Some conclusions on the development of separation bubbles on air foils are drawn from the present studies.

E. R. G. Eckert, USA

5269. Schlichting, H., and Pechau, W., Increase in lift of wings by continuously distributed suction (in German), *Z. Flugwiss.* **7**, 5, 113–119, May 1959.

The momentum and energy integrals of the turbulent boundary layer with suction are integrated under the principal assumption that the first form parameter H is constant. The condition for separation is taken to be that the second form parameter $\overline{H}$ reaches the value 1.58. The results are used to show that a more efficient increase in lift by suction is obtained by applying it over a small region near the leading edge rather than extending it over a larger region.

K. Stewartson, England

5270. Kramer, M. O., Boundary layer stabilization by distributed damping, *J. Amer. Soc. Naval Engrs.* **72**, 1, 25–33, Feb. 1960.

Author describes a novel idea for delaying boundary-layer transition by use of a built up flexible rubber coating having internal spaces filled with a damping liquid of a viscosity specified for the problem at hand. Pressure fluctuations in the boundary layer due to Tollmien-Schlichting waves deflect the surface so that the damping rubber cover will absorb energy from the oscillations. A very rough procedure for calculating the required elastic properties of the coating is described. An 8 foot long by 2.5-inch-diameter ogive nose body of revolution having an internal drag balance to measure nose drag was built. The model was tested by towing in water by a boat at speeds up to 35 kn. The first results, obtained by testing with and without the special surface, were encouraging because the best surface roughly halved the drag.

Article is of value principally for the concept rather than for the details. It is written more as a news article than as a technical article, and many questions of detail in regard to the experiments arise which are not supplied. Reviewer considers idea interesting and possibly very important. However, before the principles can be established and before the practical worth of the idea can be fully evaluated, much careful and fundamental research work must be performed.

A. M. O. Smith, USA

5271. Abarbanel, S. S., Hakkinen, R. J., and Trilling, L., Use of a Stanton tube for skin-friction measurements, NASA Memo 2-17-59W, 48 pp., Mar. 1959.

A small total-pressure tube resting against a flat-plate surface was used as a Stanton tube and calibrated as a skin-friction meter at various subsonic and supersonic speeds. Laminar flow was maintained for the supersonic runs at a Mach number of 2. At speeds between Mach number 1.33 and 1.87, the calibrations were carried out in a turbulent boundary layer. The subsonic flows were found to be in transition.

The skin-friction readings of a floating-element type of balance served as the reference values against which the Stanton tube was calibrated.

A theoretical model was developed which, for moderate values of the shear parameter, accurately predicts the performance of the Stanton tube in subsonic and supersonic flows. A "shear correction factor" was found to explain the deviations from the basic model when the shear parameter became too large. Compressibility were important only in the case of turbulent flows, and they did not alter the form of the calibration curve.

The test Reynolds numbers, based on the distance from the leading edge and free-stream conditions, ranged from 70,000 to 875,000. The turbulent-boundary-layer Reynolds numbers, based on momentum thickness, varied between 650 and 2300. Both laminar and turbulent velocity profiles were taken and the effect of pressure gradient on the calibration was investigated.

From authors' summary by A. J. Chapman, USA

5272. Davies, F. V., and Monaghan, R. J., Boundary-layer measurements on 15-deg and 24.5-deg cones at small angles of incidence at M = 3.17 and 3.82 and zero heat transfer, Aero. Res. Counc. Lond. Rep. Mem. 3133, 26 pp., 1959.

Transition measurements on 15-deg and 24.5-deg cones at M_∞ = 3.17 and 3.82 showed that the transition front was extremely sensitive to incidence, a fourfold variation occurring between transition Reynolds numbers on the leeward and windward sides of the 15-deg cone at 2-deg incidence. At zero incidence the transition Reynolds number was between 2.5 and 3.0×10^6 and no significant variation was observed over the test range of stagnation pressures from 2 to 5 atmospheres.

Pitot traverses on the top generator of the 15-deg cone at M_∞ = 3.17 showed that the effects of small angles of incidence (−2 deg to +1 deg) on the characteristics of the laminar boundary layer were nearly linear and were in excellent agreement with the theory of F. K. Moore.

The same results showed that small angles of incidence altered the thicknesses of both laminar and turbulent boundary layers, but did not affect the shapes of the velocity profiles. The alteration with incidence of the displacement thickness of the laminar bound-

ary layer was large (agreeing with Moore's theory), and in amount was more than twice that found with a turbulent boundary layer.

From authors' summary

Turbulence

(See also Revs. 5122, 5222, 5224, 5225, 5228, 5255, 5257, 5261, 5268, 5271, 5282, 5368, 5494, 5521)

5273. Yamamoto, G., Theory of turbulent transfer in non-neutral conditions (in English), *J. Meteorol. Soc. Japan* **37**, 2, 60–69, Apr. 1959.

The mixing-length theory has been extended to cover the non-neutral conditions, and, based on it, the expressions for the velocity profile applicable to conditions of any degree of stability have been derived. It is shown that the theoretical profiles agree fairly well with the observed profiles due to Rider. At the same time comparison with Rider's observations has revealed some defects of the theory, which seem to be due to neglect of the effects of radiative transfer in the present theory.

From author's summary by R. J. Mindak, USA

5274. Reichardt, H., Laws of the straight turbulent couette flow (in German), Mitt. Max Planck Inst. Stromungsforschung no. 22, 45 pp., 1959.

Investigations on the plane turbulent couette flow between straight walls have been accomplished with a new test arrangement. It was found that the equation given in an earlier paper [*ZAMM* **36**, 1, 26–29, 1956) provides a good approximation to the mean velocity distribution. In addition to this, the applicability of the well-known semilogarithmic law of the wall to this type of flow was verified. The deviations from the semilogarithmic velocity distribution which occur in the central part of the cross section are relatively small, but they differ definitively from the corresponding deviations in ordinary channel flow. A formula for the flow friction has been derived from the universal velocity function, in which the particular type of flow affects only a constant depending on the actual deviations of the velocity from the semilogarithmic law. The values of the skin friction, as calculated from this formula, were found to be in good agreement with measurements of the wall shear stress.

From author's summary by J. C. Rotta, Germany

5275. Kuethe, A. M., and Raman, K. R., Some details of the transition to turbulent flow in Poiseuille flow in a tube, AFOSR TR 59–84 (Univ. Michigan, Dept. Aeronautical and Astronautical Engng.), 31 pp., June 1959.

Measurements of velocity fluctuations, Reynolds stresses and shearing stresses at the wall in the transition region of a tube are presented. The measurements are made in a tube at a Reynolds number of 6000 behind three disturbance generators placed in the fully developed laminar flow 620 diameters from the entrance. The results show the way in which some of the statistical details of the transition depend on the nature of the disturbance generated. The Reynolds stresses and the shearing stress at the wall can reach very high values during the early stages of transition. Implications are pointed out regarding possible causes for the high-temperature recovery factor during transition in high-speed flow over surfaces.

From authors' summary

5276. Mickelsen, W. R., Measurements of the effect of molecular diffusivity in turbulent diffusion, *J. Fluid Mech.* **7**, 3, 397–400, Mar. 1960.

Townsend [*Proc. Roy. Soc. Lond.* (*A*) **224**, p. 487, 1954] has shown that turbulent vorticity may rotate and strain a diffusion wake, thereby increasing the contribution of molecular diffusion to the total mean dispersion over short diffusion times. To test whether any such effect occurs at longer diffusion times, the lateral dispersion of both helium and of carbon dioxide in air were measured downstream from a continuous point source in the turbulence produced by a grid in a wind tunnel. The data show that, for long diffusion times, accelerated molecular diffusion is negligible, so that molecular diffusion makes only an independent contribution to the total dispersion.

From author's summary by T. W. Hoffman, Canada

5277. Gurbitch, A. S., Acoustic microanemometer for investigating the microstructure of turbulence, *Soviet Phys.-Acoustics* **5**, 3, 375–377 (Letters to the editor), Feb. 1960. (Translation of *Akust. Zh., USSR* **5**, 3, 368–369, July/Sept. 1959 by Amer. Inst. Phys., New York, N.Y.)

Aerodynamics

(See also Revs. 5230, 5233, 5234, 5235, 5236, 5237, 5238, 5241, 5243, 5245, 5249, 5269, 5293, 5294, 5331, 5332, 5342, 5343, 5362, 5374, 5376, 5428, 5442, 5455, 5463, 5467, 5478, 5480, 5494, 5518)

Book—5278. von Mises, R., Theory of flight, New York, Dover Publications, Inc., 1959, xvi + 629 pp. $2.85. (Paperbound)

This new Dover edition, first published in 1959, is an unabridged and unaltered republication of the English translation first published by McGraw-Hill Book Company in 1945. Ed.

Book—5279. Abbott, I. H., and von Doenhoff, A. E., Theory of wing section including a summary of airfoil data, New York, Dover Publications, Inc. 1959, x + 693 pp. $2.95. (Paperbound)

This new Dover edition, first published in 1959, is a corrected version of the first 1949 edition with a new Preface by the authors. Ed.

5280. Smith, D. W., and Walker, J. H., Tests of an area suction flap on an NACA 64A010 airfoil at high subsonic speeds, NASA TN D–310, 43 pp., May 1960.

The lift and drag of an NACA 64A010 airfoil with a 30-percent-chord plain flap were measured, both with and without suction. The chordwise extent of perforated suction area downstream of the flap hinge line was varied. Data were obtained at a Reynolds number of 2.9×10^6 for a range of Mach numbers from 0.70 to 0.84 with several different suction-area configurations.

From authors' summary

5281. Ginzel, I., and Multhopp, H., Wings with minimum drag due to lift in supersonic flow, *J. Aero/Space Sci.* **27**, 1, 13–20, 36, Jan. 1960.

The integral equation for the lift distribution, whose solution yields the incidence distribution for the minimum induced drag of a wing of given planform in supersonic flow, is solved by an extension of the well-known Multhopp approximation method for subsonic wings. The chordwise lift distribution is developed into a Legendre series, in which only the first three terms are retained, and the integral equation is satisfied at a limited number of spanwise stations. Thus a set of linear equations results for the unknown coefficients of the Legendre development for the load at these stations. Care is taken to avoid singularities which arise from the method of approximation. The method is particularly suitable to electronic computation, and some examples are presented in the paper giving, for several wings, the local incidence distribution that ensures the minimum induced drag for a given C_L. Considerable gains over plane wings of the same planform are demonstrated. Highly sweptback wings with subsonic leading

edges give best results. Optimum wings show spanwise nonuniformity of twist and camber, that is of the load distribution; this suggests, in the reviewer's opinion, that further reductions in induced drag are to be expected if the wing planform would also be varied for an over-all optimization.

L. Z. Dumitrescu, Roumania

5282. Schaffer, A., A study of vortex cancellation, *J. Aero/Space Sci.* **27,** 3, 193–196, 233, Mar. 1960.

The cancellation of a vortex by means of another concentric vortex of equal strength but opposite spin is investigated. When such a cancellation occurs, there is a recovery of static pressure....

It is demonstrated experimentally that there exists an optimum angle of attack for the second airfoil which cancels the vortex from the first airfoil and restores uniform flow downstream of the two airfoils. A theoretical solution of this optimum angle of attack is presented, and it is found to depend upon the angle of attack of the first airfoil and upon the geometrical properties of the wings. The pressure recovery accompanying the vortex cancellation is also studied. Theoretical considerations, based on the model of a vortex filament in the center of a circular tube, show that a maximum of 63% of the static pressure drop across the first airfoil can be recovered. This maximum is imposed, irrespective of skin friction and separation losses, by the irreversibility associated with establishing a vortex field. Experimental pressure recoveries of 50% are realized....

From author's summary by E. G. Allen, USA

5283. Cheng, H. K., Hall, J. G., Golian, T. C., and Hertzberg, A., Boundary-layer displacement and leading-edge bluntness effects in high temperature hypersonic flow, AFOSR TN 59–1193 (Cornell Aero. Lab. Rep. AD 1052–A–9), 81 pp., Jan. 1960.

Both phenomena are treated theoretically and experimentally for thin bodies at high altitudes, where both effects may be equally important. The flow model consists of three layers: an inner laminar boundary, an entropy region and an outer detached shock. The assumptions are: plane steady flow, linear viscosity-temperature relation, ideal gas with constant specific heat ratio across the shock, Prandtl number equals unity, uniform body temperature, disturbance velocity and flow angle close to unity (i.e., exclusion of blunt nose region), strong shock and specific heat ratio γ close to unity. The two latter requirements restrict the investigation to the zero-order theory, but procedures for obtaining higher-order approximations are indicated. The methods involve a small perturbation procedure and existing shock-layer theory for the boundary and shock, respectively. For the entropy layer, a simple integral relation between pressure and cross-section area is based on the fact that the density in this layer is low compared to that in the free stream (nose region was excluded).

To correlate the experimental data with this theory, the similitude of Tsien and Hayes is extended. The schlieren and heat-transfer data correspond reasonably well over a wide range of varying bluntness and viscous-interaction effects. The deviations from predicted results (15–25%) are subject to an error of the order $\varepsilon = (\gamma - 1)/(\gamma + 1)$ and to the unrealized conditions of strong shocks (only $M \sim 12$ was studied) and Prandtl number equal unity ($Pr \sim 0.71$).

C. B. Ludwig, USA

5284. O'Hara, F., and Scott-Wilson, J. B., An investigation of the flow over a half-wing model with 60.5 degree leading edge sweepback at high subsonic and supersonic speeds, Aero. Res. Counc. Lond. Curr. Pap. 471, 58 pp., 1960.

Pressure measurements and surface oil flow observations have been made in the N.A.E. 3-ft tunnel on a half-wing model with 60.5 degrees leading-edge sweepback, of aspect ratio 2.828, taper ratio 0.333, and section 6 per cent RAE 101, at Mach numbers 0.81, 1.42, 1.61 and 1.82. The results at $M = 0.81$ show characteristics typical of subsonic flow over a swept wing, including leading-edge separation and a part span vortex; a physical picture of this type of flow, based on the results, is suggested. The results at supersonic speeds show a number of essentially transonic characteristics, including wing shocks and shock-induced separation; their presence is consistent with the assumption that the flow depends to some extent on conditions normal to the leading edge. From a limited analysis of the results, the pressure ratio across the shock for separation is in approximate agreement with the value for two-dimensional flow determined by Pearcey.

The possibility of reliable assessment of flow characteristics using the oil-flow method is confirmed by the close correspondence found between the flow indications from surface oil patterns and from pressure measurements.

From authors' summary

5285. Coupry, G., Unstationary aerodynamic coefficients of airfoils in supersonic three-dimensional flow (in French), ONERA Pub. 73, 47–52, Nov./Dec. 1959.

Author deals with supersonic three-dimensional flow past a wing of arbitrary shape and finite length. The rear part of the wing contains a rectangular flap which is normal to the direction of the undisturbed flow. The wing on the whole is immovable but the flap is oscillating, its front edge being the axis of rotation. Usual linearized theory is applied with idealized boundary conditions. The practical computation of the velocity potential obeying a linear partial differential equation of second order and hyperbolic type is executed with a finite-difference method; with respect to the variable x (the x-axis is parallel to the undisturbed flow) Laplace transformation is used. Finally, formulas are given for unstationary aerodynamic coefficients for pressure, lift and momentum. Numerical results are to be obtained with the help of computing machines.

R. Sauer, Germany

5286. Sandeman, R. J., The transonic characteristics of a family of two-dimensional symmetrical double wedge profiles, Part 1: Details of the programme and the zero-lift results, Aero. Res. Lab. Melbourne, Austral., Rep. A 114, 98 pp., Aug. 1959.

A systematic program of research into the transonic characteristics of four symmetrical double wedge profiles has been conducted over a Mach number range of 0.4 to 1.14 and an incidence range of 0 to 4 degrees. The report presents the results obtained at zero lift, and compares them with transonic double-wedge theory.

The pressure distribution results support the predictions of a "sonic range" where the local Mach number variations are small and provide information on the subsonic limit to this range. The strain-gage drag results are compared with the drag from the pressure distributions and the comparison provides information on the skin-friction drag forces at low subsonic and near sonic free-stream Mach numbers.

The results show that the theoretical solutions are of the right order at sonic and supersonic free-stream Mach numbers. The drag predictions of theory for this range appear to be slightly high. At subsonic free-stream Mach numbers the forebody theory agrees with the experiments except at the lowest Mach numbers and at those close to sonic. Even where boundary-layer effects are small the theoretical afterbody distributions do not agree with experimental behavior. Severe separation effects, which appear for the larger wedge angles, produce further departures from the idealized theoretical approach.

From author's summary

5287. Kelley, H. J., An investigation of optimal zoom climb techniques, *J. Aero/Space Sci.* **26,** 12, 794–802, Dec. 1959.

The problem of optimal maneuvering of a turbojet aircraft has been investigated using the Mayer formulation of the calculus of variations. The Euler-Lagrange equations have been integrated numerically by digital computation.

Arbitrary control techniques have been compared with the optimum, and it has been found that performance is relatively insensitive to piloting technique unless a time limitation is imposed which requires high maneuvering load factors.

From author's summary by A. N. Petroff, USA

5288. Nonweiler, T. R. F., The control and stability of hypersonic aircraft—an analysis of the criteria associated with hypersonic flight above the stratosphere, *Aircr. Engng.* **31,** 369, 322–329, Nov. 1959.

Conventional analytical methods are applied to stability and response problems at flight speeds approaching orbital values and at altitudes where aerodynamic and gravitational forces are comparable. The usual equations of motion are slightly modified to take into account forces resulting from the curvature of the flight path in its high velocity circling motion round the earth.

Interesting new qualitative results are obtained indicating particularly that the disturbed motion at hypersonic speeds does not display any marked stability, but is marked by a rapid incidence adjustment and a dutch roll which are harmonic oscillations if the static longitudinal and directional stabilities are positive. Lack of dynamic stability is due to inadequate aerodynamic damping at high speeds. Response characteristics are quite different from the ones encountered on high-speed airplanes.

W. Fiszdon, Poland

5289. McCarty, J. L., Brooks, G. W., and Maglieri, D. J., A dynamic model investigation of the effect of a sharp-edge vertical gust on blade periodic flapping angles and bending moments of a two-blade rotor, NASA TN D–31, 39 pp., Sept. 1959.

A two-blade rotor was subjected to sharp-edge vertical gusts while being operated at various forward speeds to study the effect of the gusts on the blade periodic bending moments and flapping angles. Variables studied included gust velocity, collective pitch angle, flapping hinge offset, and tip-speed ratio.

Dimensionless coefficients are derived for the periodic components of the incremental changes in blade flapping angles and bending moments which arise when a rotor blade penetrates a sharp-edge gust. The incremental changes in both the flapping angles and bending moments are essentially proportional to gust velocity and the coefficients express the ratio of these increments to gust velocity. The results show that the flapping coefficient usually increases with an increase in collective pitch angle, is generally dependent on tip-speed ratio, and is essentially independent of the amount of flapping hinge offset.

The bending-moment coefficient is also dependent on collective pitch angle and tip-speed ratio. Expected reductions in bending moments are realized by the use of flapping hinges, and further reductions in bending moments are achieved as the amount of flapping hinge offset is increased.

Comparison of the experimental results of this investigation with limited available theoretical results shows substantial agreement but indicates that the assumption that the response of the rotor to a sharp-edge gust is independent of the collective pitch angle prior to gust entry is probably inadequate.

From authors' summary by C. Scruton, England

5290. Rush, C. K., The icing of delta wings of unity aspect ratio having leading edge separation, Nat. Res. Counc., Canada LR–268, 38 pp., Dec. 1959.

Tests were made in an icing wind tunnel of two models, and the resulting ice formations are described and illustrated. The significance of scale is discussed, and it is shown that the tests are representative of icing conditions with large droplets and high speeds.

From author's summary

5291. Stallabrass, J. R., and Gibbard, G. A., A comparison between the spanwise and chordwise shedding methods of helicopter rotor blade de-icing, Nat. Res. Counc., Canada LR–270, 36 pp., Jan. 1960.

Flight tests in an artificial icing cloud were made on two sets of helicopter rotor blades equipped with de-icing heater mats embodying the spanwise and chordwise shedding principles. The tests demonstrated a decided performance advantage for the spanwise shedding system, although the chordwise shedding system had the advantage of greater constructional simplicity.

From authors' summary

5292. Gessow, A., and Tapscott, R. J., Tables and charts for estimating stall effects on lifting-rotor characteristics, NASA TN D–243, 45 pp., May 1960.

Rotor characteristics were calculated by numerical methods for a rotor having rectangular blades with -8° of twist with the use of a representative set of airfoil section lift and drag characteristics covering a 180° angle-of-attack range. The application of the information to various types of rotor calculations for use in estimating blade motion, performance, stability derivatives, and load factors of lifting rotors is discussed.

From authors' summary

Vibration and Wave Motion in Fluids

(See also Revs. 5099, 5253, 5261, 5310, 5442, 5452, 5459, 5490, 5494, 5498, 5534)

5293. Gundersen, R., The non-isentropic perturbation of an arbitrary simple wave, *J. Math. Mech.* **9,** 2, 141–145, Mar. 1960.

Paper is concerned with one-dimensional unsteady flows of an ideal, inviscid compressible gas, not necessarily isentropic, which are small perturbations of an arbitrary simple wave. Such perturbations can be specified by three arbitrary functions, corresponding to waves in each direction and an entropy perturbation. By linearizing the equations for the perturbed quantities an explicit solution of the problem is obtained in terms of these functions and functions specifying the basic simple wave. Paper is an extension of a previous one [AMR **12**(1959), Rev. 4610] and solution is now completely general. Solution is mathematically formal and no application to a specific problem is given, but explicit form of solution makes such applications straightforward.

P. M. Stocker, England

5294. Phillips, O. M., Centrifugal waves, *J. Fluid Mech.* **7,** 3, 340–352, Mar. 1960.

The familiar problem of almost rigid-body motion of an incompressible fluid rotating in a cylinder with its axis in a horizontal position is examined analytically. Assuming the fluid is inviscid and small perturbations to rigid motion, the criterion for stability of motion is established. These assumptions are confirmed experimentally. The modes of oscillation of the free surface are examined and a frequency equation is deduced. Two particular modes are then analyzed using the deduced equation and the results compare favorably with observed frequencies.

J. F. Lee, USA

5295. Gouda, M. A., Hydrodynamic wave pressure on breakwaters, *Proc. Amer. Soc. Civ. Engrs.* **86,** WW 1 (*J. Water Harbors Div.*), 13–25, Mar. 1960.

Paper develops analytically the pressure distribution over an impervious, vertical wall exposed to periodic gravity waves arriving at normal incidence in water of infinite depth. By reflection, a standing-wave pattern in formed. The wave pressure, computed to the second order in wave steepness has a second-order term

which does not vanish at great depths. Reviewer believes that this term, which has been discussed by M. S. Longuet-Higgins [*Phil. Trans. Roy. Soc.* (*A*) **243**, 1, 1950], will vanish for waves arriving not exactly at normal incidence. Author compares his results with empirical formulas of Luiggi, Sainflou, Cagli, and Benedict. C. Cox, USA

5296. MacCamy, R. C., On the scattering of water waves by a circular disk, AFOSR TN 59-1261 (Carnegie Inst. Technol., Dept. of Mathematics TR-30), 26 pp., Dec. 1959.

The three-dimensional problem of the title concerns diffraction by a circular disk lying in the undisturbed free surface. It is shown to possess an existence theorem derivable from the corresponding theorem in two dimensions of Rubin [*Comm. Pure Appl. Math.* **7**, 2, 317-344, 1954]. Also, the singularity at the edge of the disk is shown to be of the same form as that studied by Lewy [Univ. Calif. Publ. Math. **I**, 247-280, 1950] in the corresponding problem in two dimensions.

No numerical solutions are given but it is suggested that the method may be practical in obtaining them. Author further suggests existence of other boundary-value problems for elliptic equations in three dimensions which essentially reduce to some two-dimensional harmonic problem.

J. N. Hunt, England

5297. Taylor, G., The dynamics of thin sheets of fluid, Parts 1, 2, and 3: Water bells; Waves on fluid sheets; Disintegration of fluid sheets, *Proc. Roy. Soc. Lond.* (*A*) **253**, 1274, 289-321, Dec. 1959.

In Part I, a general differential equation describing the shape of an axially symmetric sheet of fluid is presented. A closed solution is obtained for the simple case of equal pressure inside and outside of the water bell and of negligible gravitational effect. Calculated results compare very favorably with meassurements. Effects of air friction were investigated using an analysis performed by Howarth. It is effectively the calculation of skin friction due to the adjacent laminar boundary layer in air.

In Part II, the behavior of capillary waves in thin fluid sheets is discussed. It is found that they are of two kinds: (1) antisymmetrical waves in which displacements of opposite surfaces are in the same direction and (2) symmetrical waves in which the displacements are of opposite direction. The antisymmetrical waves are nondispersive. When the thickness of the sheet t is small compared to wavelength λ, such waves are propagated at a speed independent of wavelength which is given by $\sqrt{\frac{2T}{\rho t}}$, T being the surface tension and ρ the fluid mass density. It is analogous to sound waves. In a sheet of uniform thickness moving with constant speed u, a point disturbance produces line-like waves at angles $\pm$ arc sin $\sqrt{W}$ to the flow direction, where W is the Weber number $\frac{2T}{\rho t u^2}$. When the sheet is expanding radially, the corresponding disturbances assume the form of cardioids. An interesting technique was described for photographing the wave patterns.

The symmetrical waves are highly dispersive and, as such, are more difficult to analyze. They are propagated at a much slower rate. An approximate treatment indicates that a point disturbance in a moving sheet of uniform thickness produces parabolic waves with their common axes lying downstream from the origin. The wave pattern due to the motion of a pressure point is also discussed. When the sheet is expanding, the waves are of a more complicated nature. Symmetrical wave patterns as revealed by schlieren photographs agree reasonably well with theoretical predictions.

In Part III, the problem of disintegration of free edge of thin fluid sheets is examined. From a consideration of the dynamics of the edge, author found that a straight free edge bounding a fluid sheet of uniform thickness moves at a speed equal to that of the antisymmetrical waves. Hence the angle between it and the direction of motion is again arc sin $\sqrt{W}$. Both waves and edge remain fixed in space. Photographs taken during experiments on antisymmetrical waves confirm this.

In a radially expanding sheet, there is a limiting radius R beyond which the sheet cannot extend. This occurs when the Weber number equals unity for an inviscid fluid and when there is no turbulence. The analysis agrees well with the experimental findings of Savart. It also indicates the feasibility of determining surface tension under dynamical conditions. At or just prior to the attainment of the critical radius, the edge becomes unstable and it breaks up into droplets. Calculation reveals that only a very small fraction of the kinetic energy in the original sheet was carried away by the drops in the form of surface energy. The main portion of it was dissipated through turbulence within the drops.

Edges formed by a small obstacle in an expanding sheet do not coincide with the cardioids described in Part II, if the free edge does not disintegrate. Equations were given for calculating its shape. On the other hand, if the edges break up into drops, they will assume the cardioid form.

Author concludes this part by considering the mechanism of disintegration of fluid sheets produced by a swirl atomizer. An expression for the order of magnitude estimation of the droplet size is given. B. T. Chao, USA

5298. Miles, J. W., Free surface oscillations in a rotating liquid, *Physics of Fluids* **2**, 3, 297-304, May-June 1959.

The disturbed motion of a liquid having a free surface in a vertical, rotating, circular cylinder and an equilibrium distribution of velocity corresponding to rigid body rotation is studied in linear approximation. It is shown that a vertical gradient of velocity necessarily generates vorticity, whence the disturbed motion cannot remain irrotational. (Earlier studies of this problem were based on shallow-water theory, in which approximation the disturbed motion can remain irrotational.) The natural frequencies for the free surface oscillations are studied in some detail for a deep tank (say, depth > diameter), and it is found that one effect of rotation is to split the pairs of frequencies that would have been of equal magnitude and opposite sign for the nonrotating liquid. In addition, new resonant frequencies are found that have no counterpart for a nonrotating liquid and for which the motion does not fall off exponentially with depth. The results are applied to forced, transverse oscillations of the tank, and explicit solutions are given for three special cases.

From author's summary by H. Ashley, USA

5299. Nikorov, P. S., The principle involved in the action of a pneumatic breakwater (in Russian), *Nauchn. Trudi Odessk. In-ta Inzh. Morsk. Flota* no. 16, 24-29, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6270.

Three principal factors in the damping of waves are differentiated: (1) air bubbles, (2) an ascending flow of liquid, (3) a surface flow. Results are given of experiments performed on three types of models, which made it possible to evaluate separately the extent of the participation of the three factors mentioned in the damping of the waves. The models were placed in a wave-making tank $12 \times 0.8 \times 0.75$ m with wave heights equalling 15 to 20 cm. The conclusion reached as the result of the experiments was that the principal damping agent was the oncoming surface flow, while the influence of the air bubbles in the ascending flow was insignificant. An explanation is given of the wave-damping mechanism by the surface flow. An empirical formula is furnished

$$2b = \frac{i_{\kappa p}\, k\, 2L}{32^{\nu}\,(1 + 132 v^3 i^3)} \qquad \left(v = \frac{v}{c}\right)$$

where $2b$ is the height of the wave beyond the breakwater, $2L$ is

its length, i_{cr} is the critical steepness of the wave ($i_{cr} \approx 0.15$), $\kappa \approx 0.8$, v is the maximum velocity of the surface flow, c is the velocity of the wave's propagation. The problem considered has been the subject of a number of studies [see, for instance, A. A. Dmitriev, T. V. Bonchovskaya, A. V. Teplov, *Trudi Gidrofiz. In-ta, Akad. Nauk* **5**, 24-38, 1955]. V. S. Voitsenya

Courtesy Referativnyi Zhurnal, USSR

Book—5300. Stucky, A., Surge chambers [Chambres d'équilibre], 3rd ed., Lausanne, Sciences and Technique, 1958, xi + 182 pp. (Paperbound)

Primarily intended as textbook, this monograph is also a useful reference work for practicing engineers dealing with problems of design or operation of hydraulic power plants and waterworks. In eight chapters it treats phenomena occurring in the surge chambers of hydraulic conduits, in particular, water hammer and oscillations of water level, which occur on closing or opening of the discharge valve. After a general description of the layout of water conduit and of the functioning of the surge chamber, the phenomenon of water hammer is explained in general terms, as it occurs at instantaneous, rapid, and slow closure of the discharge valve. Several chapters deal with the calculation of water hammer by the graphical analysis based on the previous work of Bergeron and Schnyder, and numerous concrete examples have been worked out illustrating various conditions such as: (1) neglecting frictional losses, (2) taking frictional losses into consideration, (3) oscillations of water level in the surge tank having various shapes and dispositions.

Basic equations are derived for relationships between flow velocity, energy loss, cross-sectional area of surge chamber, water level in surge chamber, and rate of discharge. Simplified methods of Pressel and Schoklitsch, using small time intervals during which the conditions are assumed to be constant, are also treated and illustrated with examples. Oscillations of water level due to control maneuvers, and to sudden change of power demand are treated mathematically and graphically. A chapter treats surge chambers of more complicated types, with restrictive apertures, auxiliary chambers, differential chambers, and their combinations.

In this otherwise competent work reviewer found no reference to the extensive American literature on this subject. Furthermore, reviewer believes that a few examples, representing pressures and velocities in three-dimensional charts as functions of location and time, would have facilitated understanding of the phenomena discussed, and would have enhanced the value of the book for instructional purposes. K. J. DeJuhasz, USA

5301. de Juhasz, K. J., Graphical analysis of transient pressure and velocity changes in the fuel injection systems of diesel engines (in English), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **27**, 1/2, 53-64, 1959.

For regular and economical operation of diesel engines it is necessary to feed the fuel oil into the combustion chamber of the engine at a predetermined speed, pressure, and duration. Owing to the compressibility of the fuel, and to the finite velocity of propagation of a disturbance, the process of nozzle discharge differs from the process of pump delivery, which, in general, has an adverse effect on the engine operation. In the present investigation, by a graphical method developed by the author, the process of nozzle discharge is determined for a given process of pump delivery. Furthermore, it is determined under what special conditions the process of nozzle discharge will be equal to the process of pump delivery. The principles and procedures of the graphical analysis are explained, and it is pointed out that it can be advantageously applied also to other than hydraulic transient elastic phenomena. From author's summary

5302. Gundersen, R., Simple wave flow in ducts, *Physics of Fluids* **2**, 6, 680-687, Nov./Dec. 1959.

Problem considered is perturbation of a simple one-dimensional rarefaction wave advancing into a perfect gas at rest by gentle changes of duct area. The two cases considered are a divergent (or convergent) section or a throat. Linearized, small-perturbation theory leads to straightforward integration of these cases. The case $\gamma = 5/3$ is mathematically singular but qualitatively similar to other cases. Certain results obtained by Chester by a more elaborate study are confirmed. Work is interesting as an example of the study of a fairly complicated flow by simple analytical methods. There is no discussion of practical significance or related experiments. J. A. Shercliff, England

5303. Pohl, K. H., Unstationary pressure field in the neighborhood of a ship propeller and the periodic forces produced in its neighborhood (in German), *Schiffstechnik* **6**, 32, 107-116, June 1959.

As a contribution to the problem of ship vibrations, the magnitude of the unsteady pressure distribution around a propeller has been calculated. The propellers are replaced by a vortex line. The resulting pressures in the form of Fourier coefficients are presented in tabular form. In particular, the periodic force which acts on an infinite plate is calculated exactly by integrating the pressures. The force is vanishing except for a propeller with one vane only.

Further approximate calculations are performed with the aim of obtaining the forces on objects in the neighborhood of propellers which are similar to parts of the ship. Such objects are simulated by finite plates, cylinders parallel to the axis of the propeller, etc.

Measurements which corroborate the analysis will be carried out in the future. H. P. Eichenberger, USA

5304. Odol'skii, E. Kh., Wave resistance in long gas pipe lines (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Energetika* no. 4, 81-83, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6161.

The motion of a gas in a conduit of sufficient length is associated with the appearance of a wave resistance governed by the presence of inertia forces with accelerated motion of the gas. A relation is obtained in this paper which permits the determination of the correlation between the wave and the full resistance on the assigned section of the gas conduit. It was shown that for 90% of the length constituting the critical length of the gas conduit (the conditioned length of the gas conduit at the end of which the pressure is equal to zero) the wave losses were less than 1% of the full losses. At the end of the gas conduit of an extent of $0.96L_{cr}$ the magnitude of the wave resistance was ~9% of the full loss of pressure. With a length of pipe conduit larger than $0.96L_{cr}$ the wave losses increase sharply and may be several times greater than the loss due to friction. Yu. A. Lashkov

Courtesy Referativnyi Zhurnal, USSR

5305. Belsheim, R. O., Response motions of a submarinelike cylinder caused by underwater explosions, *Noise Control* **6**, 2, 11-17, Mar./Apr. 1960.

In this qualitative discussion of responses of a cylinder to underwater explosions the purpose has been to consider motions useful as shock inputs to items internally attached to the cylinder. For this reason the response treatment is by no means complete, if cylinder strength is of concern. The geometries considered were those which would cause significant cylinder response, so far as internal items are concerned. For a charge near the target the gross responses for broadside and vertical loading were considered; for a large charge distant from the target the gross responses for broadside, vertical, and end-on loading were considered. Since secondary response of equipment internal to the cylinder is of interest, brief mention of the normal mode design-analysis method and shock spectra was made. From author's summary

5306. Urick, R. J., Side scattering of sound in shallow water, *J. Acoust. Soc. Amer.* **32,** 3, 351–355, Mar. 1960.

Paper describes measurements to determine the horizontal directivity of bottom scattered sound at 22 kc. A hard sandy bottom in shallow water was studied. The author finds the scattering in the horizontal plane to be isotropic within the angular range from the backward direction around to 150° in the forward direction.

A. D. Voorhis, USA

5307. Mintzer, D., and Tanenbaum, B. S., Spatial and temporal absorption in a viscous medium, *J. Acoust. Soc. Amer.* **32,** 1, 67–71, Jan. 1960.

The relation between spatial and temporal absorption for acoustic waves in a viscous medium is discussed by considering the problem of a viscous-liquid-filled tube with a piston at one end and a reflecting termination. The solution of the problem is found in terms of traveling waves from image sources, and standing waves in a tube. The phase velocity and attenuation of the steady-state terms for both solutions are the same. The transient part of the standing-wave solution gives rise to the usually plotted velocity and temporal attenuation; it is shown that these do not have the same meaning as in the spatial absorption case, since they depend upon the allowed wave numbers of the system, that is, upon the geometry and boundary condition.

From authors' summary by E. Ackerman, USA

5308. Chetaev, D. N., On the driving of a piston with a rigid collar into an elastic half-space, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 3, 610–621, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N.Y.)

Author, in an acoustically oriented approach, studies the problem of the excitation of an elastic half-space driven by a piston. As to be expected he concentrates his attention on the active and reactive resistance at the point of application of the driving force. His reference to the literature is exceedingly sparse. In this connection the reviewer calls attention to the work by Eric(h) Reissner on the elastic half-space. In particular, he refers to the very pertinent paper entitled "Stationäre, axialsymmetrische, durch eine schüttelnde Masse erregte Schwingungen eines homogenen elastischen Halbraumes [*Ing.-Arch.* VII, pp. 381–396, 1936].

W. H. Hoppmann, II, USA

Fluid Machinery

(See also Revs. 5230, 5294, 5303, 5324, 5327, 5534)

Book—5309. Schulz, H., Pumps (Die Pumpen), Berlin, Springer-Verlag, 1959, viii + 248 pp. DM19.50.

Book presents current pump design and construction techniques employed for the delivery and transport of liquids. Analysis of centrifugal, axial and displacement-type pumps is supported by performance curves and 257 figures. Topics treated include the layout of impeller and diffuser vanes, velocity diagrams for blade elements and cascades, propellor layout and a treatment of jet pumps and positive displacement-type pumps. Included are detail drawings of pump installations, multi-staging, and housing details. Reviewer finds emphasis to be on the applied with an appreciation of fundamental principles well expressed and undergirding the book.

R. L. Leutzinger, USA

5310. Calvert, N. G., Hydraulic ram as a suction pump, *Engineer* **209,** 5437, p. 608, Apr. 1960.

5311. Crossland, B., and Alexander, R. L., Airhydropump: A high pressure intensifier, *Engineering* **189,** 4902, 462–463, Apr. 1960.

5312. Medici, M., Aerodynamical research on axial turbomachinery by reversible flow (in Italian), *Ric. Scient.* **30,** 2, 232–240, Feb. 1960.

Experimental contribution to the problem of combined axial turbomachinery for reversible flow conditions. A single axial impeller was studied and tested for reversible flow-conditions.

From author's summary

5313. Vavra, M. H., The influence of imposed energy gradients on the flow in turbomachines (in German), *Forsch. Geb. Ing.-Wes.* **25,** 3, 79–91, 1959.

The equations of motion are derived using rectangular curvilinear coordinates for an inviscid axisymmetrical flow in unbladed annular channels of arbitrary wall curvature. The proposed calculating procedure permits the establishment of the influence of the flow curvature and change in total head across the channel on the velocity distribution. This case is of special importance for the flow between the blade rows of multistage axial turbomachines with an entrance stage of variable total work over the blade height. Some calculated results given for this type of compressor show the possibilities to get desired axial velocity distributions or blade loadings over the blade height.

N. K. H. Scholz, Germany

5314. Zakharenko, S. E., Calculations for rotary compressors (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 2, 90–104, 1954; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6204.

A description is given of the calculations for rotary compressors which compress the gas with a change in the volumetric capacity of the working chamber. An analysis is furnished of the influence exerted by various factors on the production, the delivery coefficient, the power and the coefficients characterizing the work of the machine. The method proposed enables all the characteristics to be determined prior to the assembly and testing of the compressor: production capacity, power, coefficients of delivery and efficiency and the functions for the degree of compression and the number of revolutions.

B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

5315. Gur'ev, V. P., Analysis of pivotal-bladed reversible assembly (a turbine pump) (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 193, 5–23, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6376.

The question of working out reversible assemblies (a turbine and a pump combined in one machine) is linked with the necessity to provide hydroaccumulating electric stations in separate power systems. The accumulation of water energy at hydroelectric stations (H.E.S.) is intended to even out the load curve of the power system by utilizing the energy of the basic H.E.S. during periods of low loading (generally during the night by assemblies working as pumps) and the avoidance of peak loads when the assemblies are functioning as turbines. The most effective of these systems of accumulation requires the turbine assembly of the H.E.S. to be reversible and able to function as a pump with relatively high indicators. In conjunction with the above problem the connected one of production of a pivotal-bladed reversible assembly with different directions of rotation was solved: at the beginning of work with the calculated head of $H = 18$ m and then with $H = 7$ m. The calculations for the axial wheels of the reversible assembly were carried out by A. F. Lesokhin's hydromechanical method, while those for the blades of the distributor followed the methods of I. N. Voznesenskii-V. F. Pekin.

A detailed calculation and experimental investigation was made on the influence of various factors (the form of blade outlines, the density of the lattice, the distribution of the circulation, the geometry and dimensions of the assembly, and so forth) on the efficiency and on the cavitation characteristics of the assembly when working as a turbine and as a pump. The completed calculations and tests of the working components of the reversible assembly

showed that the adopted methods of hydrodynamic calculation justified themselves and enabled efficiency (k.p.d.) values to be obtained on the assembly closely approximating those of an ordinary turbine. When working as a pump the efficiency (k.p.d.) of the reversible machine is markedly reduced, principally at the expense of the influence of the thrust channels having the shape of bends. It was found possible to obtain somewhat higher efficiency and better cavitation properties from a reversible assembly working as a pump by making revised calculations for the working parts on the parameters of this regime, but this leads to a certain amount of reduction of the power indicators in the turbine regime. Detailed deductions are furnished for the calculation-experimental investigation and for the items of an analysis of the section of the turbine between the inlet and outlet valves, for pivotal-bladed reversible hydro assemblies working at given heads of water. The universal and cavitation characteristics of different types of wheels were obtained when working as a turbine and as a pump. Indications are given of the trend of future investigations to improve the efficiency (k.p.d.) and the cavitation properties of the assembly, both in the capacity of a turbine and of a pump. V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

5316. Vasil'ev, A. M., The suction capacity of a screw-type pump (in Russian), *Trudi Vses. N.-i. In-ta Gidromashinostr.* no. 22, 138–152, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6379.

The lifting capacity of screw-type pumps, working on oils, is investigated. The paper describes the cavitation properties of a number of screw-type (Archemedian) pumps fitted with cycloidal gear, tested by the VIGM in 1949–1952, and the results of the measurement of pressures in a set of sections of this type of pump. The elastic properties of an oil in static conditions were investigated with the aid of special apparatus. The author was able to propose a method of approximate calculation for the cavitation characteristics of screw-type pumps, as the result of comparing the cavitation characteristics obtained with an oil free from air bubbles with the static elastic characteristics of the oil.

V. N. Gusev

Courtesy Referativnyi Zhurnal, USSR

5317. Bogdanovskii, V. I., Influence of a radial clearance in a wheel on the work of a radial pump (in Russian), *Trudi Vses. N.-i. In-ta Gidromashinostr.* no. 22, 114–124, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6378.

Author investigates the title problem, the diameter of the wheel's casing and the diameter of the wheel's blades both being constant. It was shown that when the pump is at its maximum efficiency increase in the radial clearance leads to a decrease in the useful hydraulic power and the efficiency mainly at the expense of the pressure. The theoretical characteristics of the pump do not depend on the alteration of dimensions of the clearance when the diameter of the wheel's casing is increased and shifts almost parallel to the side of lowered pressures with increase in the clearance by means of reduction in the diameter of the blades of the wheel. The pressure of a radial clearance is a condition governing the increase of the circulation and the decrease of the axial velocity in the flow after the wheel. The pressure on the outer radii of the blade from the pressure side and also C_y of the profile decrease with increase of the clearance at angles of attack greater than the optimum for efficiency. V. N. Gusev

Courtesy Referativnyi Zhurnal, USSR

5318. Ashby, G. C., Jr., Investigation of the effect of a guide-vane-rotor combination on inlet total-pressure distortions in compressible fluid, NASA TN D-123, 15 pp., Dec. 1959.

The total-pressure distortion produced by a 31% open plate was measured upstream and downstream of the rotor of a guide-vane-rotor combination which was designed to have a 90° included angle at all radial stations. The average relative number was 0.65 and the average density ratio across the rotor was approximately 1.12.

The distortion was greatly reduced across the rotor. Comparison of the downstream measured distortion with that estimated by using the recovery ratio equations of Smith [*Transactions American Society of Mechanical Engineers* April 1958] shows that the magnitude of the distortion behind the rotor was estimated with reasonable accuracy by the equation for an incompressible fluid.

From author's summary by J. C. Geyer, USA

5319. Kerwin, J. E., Machine computation of marine propeller characteristics, *Inter. Shipbldg. Prog.* **6,** 60, 343–354, Aug. 1959.

The flow about propellers represents a three-dimensional velocity field with an angular periodicity. The numerical study of this field with a fair accuracy requires very extensive calculations. [See e.g. AMR **6**(1953), Rev. 691, and "Die Berechnungskurven" published by G. Braun, Karlsruhe, 1955]. It is, therefore, understandable that for practical applications every endeavour is made to find simplified methods which, while being sufficiently elementary to produce results without excessive work, conform reasonably well to actual conditions. However, all such simplified methods, as is well-known, have two weak points: (1) they are based on the theory of infinitely long lifting profiles and (2) they do *not* consider the distribution of the velocities induced by the free vortices along the profile surface of the cylindrical sections through the propeller blade.

Thus any attempt to evaluate the accuracy of the simplified methods deserves high praise. In this respect, not only have the characteristics computed according to the different methods been compared, they have been compared with measured values, a feature which makes the paper extremely valuable.

In the present publication the characteristics of 21 marine propellers have been calculated and compared with the values as measured. The investigation covers only open-water propellers without considering the wake.

The calculations have been made according to the simplified methods proposed by van Manen ["Fundamentals of ship resistance and propulsion," Publication no. 132-a of the NSMB] and by Eckhardt and Morgan ["A propeller design method," SNAME, 1955]. The test results have been taken from the publication by L. Troost: "Open water test series with modern propeller form," NECIES, 1951. These results have been presented in graphical form.

The results obtained with both methods sometimes differ considerably from one another. Also the discrepancy between calculated and measured values is considerable. This applies in particular to propellers with high pitch ratios.

The extensive calculation work could be carried out only with the aid of modern high-speed electronic computers.

M. Strscheletzky, Germany

Flow and Flight Test Techniques and Measurements

(See also Revs. 4996, 5122, 5225, 5233, 5234, 5241, 5258, 5263, 5277, 5284, 5290, 5291, 5294, 5353, 5356, 5372, 5442, 5450, 5533, 5534)

5320. Pass, H. R., A semi-automatic McLeod gauge, AFOSR TN 60-399 (Univ. So. Calif. Engng. Center Rep. 56-211), 36 pp., Mar. 1960.

A semi-automatic McLeod gage has been designed and built for use in the USC low-density wind tunnel. The gage is mounted inside the tunnel and is remotely controlled and remotely read. Control is obtained by means of an electro-pneumatic circuit using

electrodes that are inserted through the glass walls; the reading is obtained electrically using a circuit consisting of, in part, a constant-current generator, tungsten wires that are placed in the bores of the capillaries, and a strip-chart recorder. The design is relatively simple, inexpensive, and reliable; operationally it is somewhat unwieldy. From author's summary

5321. Lin, S.-N., The design and testing of barometric type absolute altimeter with atmospheric temperature correction mechanism (in English) *Scientia Sinica* **7**, 1, 121–130, Jan. 1958.

5322. Samoilov, V. N., The piston-balancing errors of weight-and-piston pressure gages, *Measurement Techniques* no. 3, 178–181, May 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 3, 19–20, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5323. Maizel', M. B., Pressure gage with an aneroid-electrical measuring element, *Measurement Techniques* no. 1, 15–18, Mar. 1960. (Translation of *Izmerital'naia Tekhnika, USSR* no. 1, 15–16, Jan. 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

5324. Gibson, N. R., Experience in the use of the Gibson method of water measurement for efficiency tests of hydraulic turbines, *ASME Trans.* **81** D (*J. Basic Engng.*), 4, 455–487, Dec. 1959.

Purpose of this paper is to examine experience during the years 1920 to 1955 in the use of the Gibson method and apparatus for measuring the flow of water as applied in field efficiency tests of turbines in hydroelectric power plants.

Diagrams, based on tables of maximum efficiencies of comparable units, from a total of 310 tests are presented. A few unusual experiences are cited and described. A comprehensive discussion is given of the precision which can be expected in determining the various factors required for measuring water quantities by this method.

Four appendices give: (1) A brief description of the Gibson method and apparatus; (2) some slight revisions of the author's original paper published by ASME in 1923; (3) a numerical example of the delineation and computation of a differential pressure-time diagram; and (4) a partial bibliography with notes.

From author's summary by E. Eujen, Germany

5325. Kivilis, S. S., On the problem of the design of flowmeters, *Measurement Techniques* no. 5, 598–600, Feb. 1960. (Translation of *Izmeritel'naia Tekhnika USSR* no. 5, 84–86, Sept./Oct. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

Author has developed equations and charts to permit predictions of discharge change with minute change in flowmeter throat diameter. D. G. Huber, Canada

5326. Kudryashev, A. F., The investigation of channel phenomena on aerodynamic models (in Russian), Some new hydrometeorological and geographical methods of measurement and measuring instruments, Leningrad, Gidrometeoizdat, 1957, 139–180; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 8775.

Paper commences by giving a brief historical survey of aerodynamic tests made by a number of research workers for the investigation of hydraulic, hydrodynamic and hydrological processes and phenomena; then follows an account of the existing, theoretical principles of the modelling of liquid (water) flows by aerodynamic analogues, i.e. by models placed in wind-tunnels, usually under conditions of two-dimensional flow. For the investigation of channel phenomena the upper part of the wind-tunnel is made of thick glass; the lower half is then a relief model of the channel under investigation, with all structures and installations. In view of the fact that, in such an arrangement, the vertical distribution of the velocity has a maximum toward the glass top, it is usually assumed that at the point v_{max}, the flow can be divided into two parts. By determining the velocities at, and the ordinates of, this "interface," according to P. N. Belokon and V. M. Makkaveyev, the author claims, on the basis of experimental material obtained by Yu. V. Klementich, that Makkaveyev's formulas give the better results. The author also establishes three nondimensional constants for the formation of deposits:

$$\frac{L}{d}, \quad \frac{C_2 d}{\nu}, \quad \frac{\gamma_H^2 C_2 \alpha}{\gamma \mu};$$

where L is characteristic length (e.g., height, length and width of a sandbar), d mean diameter of the soil particules, C_2 velocity of displacement of the deposit (e.g., a sandbar), ν kinematic viscosity of the medium, γ_H volume density of the deposit; γ volume density of the flowing medium; μ coefficient of dynamic viscosity of the medium (air). All three characteristics are associated with the Froude and Reynolds numbers; with increasing value of these numbers, the linear characteristics at first decrease, then slowly increase, while the two last grow. The author nowhere proves or verifies these functional relationships, nor gives any explanation thereof. In conclusion, the paper describes experiments on the modelling of an existing river bar, the data for which were obtained on the site by a special field party whose task was to determine the flow velocities, slopes of the water surface, data on the movement of deposits and their grain size (screen analysis), etc. The sand was modelled by means of dry tobacco ash. The qualitative picture of the movement of deposits was, in the author's opinion, satisfactorily reproduced in the model (even including blasting operations) to a horizontal scale of 1:50, a velocity scale of 13:1; and a scale of the bottom deposits of 1:128, flow volumes, 1:20,000 and the time of re-formation of the river bed, 1:5,000. N. P. Zrelov

Courtesy Referativnyi Zhurnal, USSR

5327. Vashkevich, K. P., Control of high-speed wind motors by turning the vanes by means of aerodynamic forces (in Russian), Industrial Aerodynamics (Prom. Aerodynamika), Moscow, Oborongiz no. 8, 78–137, 1957; *Ref. Zh. Mekh.* no. 6, 1959. Rev. 6011.

Basic results are given, both theoretical and experimental (carried out on models in a wind tunnel and also on a full-scale wind motor type 1D-18 TsAGI), of the investigations on the control of high-speed wind motors by turning the vanes by means of aerodynamic forces. The study consists of the following sections: the special features of control of wind motors; the characteristics of the transmission mechanisms of the regulator; the kinematics of the regulator; the static characteristics of control; the equations for the motion of the system; the regulator's stability; investigation of the controlling process; the analysis of the motion of the system when the governor of an inertial accumulator is operating; the determination of the parameters of the regulator from the conditions of stability. It is shown that the proposed method of calculation for the problem stated in the title furnishes the possibility for a comparatively easy determination of the static characteristics of control and for finding in relation to these characteristics the parameters of the regulator itself. In addition, it offers the possibility of a simple solution of the problem regarding the investigation of the work of the wind motor on the dynamic regime with different external reactions affecting both the motor and the regulator. Proof is given that in the problem being investigated the method of small vibrations is fully utilized, as this method in many cases yields not only qualitative results but also quantitative results of an accuracy sufficient for all practical purposes. The control of high-speed wind motors by turning the vanes by means of aerodynamic forces guarantees great flexibility in the adjustment, in the determined linkage between the moving moment and the wheel's revolutions and the presence of aerodynamic damping, which en-

ables the system to be a system of direct control, stable even without taking friction into account.

The results of the approximate investigation of the process of control when transmission of an inertia accumulator is operating in the system give opportunities in the designing of a similar plant to concentrate tentatively on the mutual bond of the moment of inertia of the wind wheel and the coefficient of torsional stiffness of the transmission q_s. It was established that with one and the same moment of inertia of the wind wheel the system can only be made stable at small or at large values for q_s, as between these values there exists a large region of instability.

A. I. Bunimovich

Courtesy Referativnyi Zhurnal, USSR

5328. Butler, S. F. J., and Guyett, M. B., Low-speed wind-tunnel tests on the De Havilland Sea Venom with blowing over the flaps, Aero. Res. Counc. Lond. Rep. Mem. 3129, 55 pp., 1959.

The reduction in approach speed of 10 to 15 kt predicted from the tunnel results was later achieved in flight. The tunnel results suggested a beneficial reduction in minimum-drag speed due to blowing, particularly at large flap angles. Trim changes were large, amounting to about 8 deg on the all-moveable tail at flaps 60 deg.

It is shown that, while the lift and pitching-moment increments resulting from flap blowing can be estimated fairly closely, the drag increments at large flap angles are much larger than would be expected.

A flight-tunnel comparison is included of the lift increments resulting from blowing. At flaps 40 deg, agreement is good, but at larger flap angles, the lift increments measured in flight were less than those measured on the model.

From authors' summary by J. M. Evans, Australia

5329. Hall, H., and Rein, J. A., Wind tunnel tests on the flutter of a swept and unswept wing with ailerons, Aero. Res. Counc. Lond. Curr. Pap. 478, 13 pp., 1960.

Details are given of low-speed flutter tests on an unswept and 40° sweptback wing, each wing having a half-span, quarter-chord aileron. The aileron mass balance and hinge stiffness were varied in the tests. Flutter calculations were made for both wings and show general agreement with experimental results.

From authors' summary

5330. Evans, A. J., and Liner, G., A wind-tunnel investigation of the aerodynamic characteristics of a full-scale supersonic-type three-blade propeller at Mach numbers to 0.96, NACA Rep. 1375, 42 pp., 1958.

The investigation was made in the Langley 16-ft transonic tunnel with a 6000-horsepower propeller dynamometer. The tests covered a range of blade angles from 20.2° to 60.2° at forward Mach numbers up to 0.96. The effects of compressibility on the aerodynamic characteristics of the propeller and comparisons of the experimental results with calculated results are presented.

From authors' summary

5331. Darling, H. G., and Sandeman, R. J., High speed wind tunnel tests on a straight wing having aerodynamic sweep, Aero. Res. Lab. Melbourne, Austral., Rep. A 116, 43 pp., Aug. 1959.

Poole and Stephens of Sydney University have developed a method of obtaining aerodynamic sweep on a straight wing by the suitable choice of spanwise variation in section profile. At low speeds, the lowest pressure isobar was swept altemately backward and forward across the span at a mean angle of 36°. To determine the high-speed characteristics of this wing, pressure distributions and strain-gage force measurements were obtained at Mach numbers up to 0.95 on a two-dimensional model.

From the pressure distributions it was apparent that

(1) The isobars were unswept near the surface discontinuities at all speeds.
(2) With increases in speed up to the critical there was a progressive reduction in the angle of sweep of the isobars.
(3) Beyond the critical speed a change in the form of the section pressure distributions greatly reduced the sweep of the isobars immediately upstream of the pressure recovery region.

The force measurement showed that there was no significant improvement in the drag rise characteristics of this wing when compared with an equivalent wing having unswept isobars.

From authors' summary

5332. Tosti, L. P., Flight investigation of stability and control characteristics of a 1/8-scale model of a tilt-wing vertical-take-off-and-landing airplane, NASA TN D-45, 25 pp., Mar. 1960.

Tests were made of hovering flights in still air, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight. The model had two six-blade dual-rotating propellers mounted on a wing tiltable up to an incidence angle of approximately 90°. Two wing spans were used. The model had conventional aileron, rudder, and elevator controls for forward flight. For hovering flight the ailerons provided yaw control, an air jet at the tail provided pitch control, and differential total pitch of the propellers provided roll control.

From author's summary

5333. Tosti, L. P., Flight-test investigation of the stability and control characteristics of a 1/8-scale model of a tilt-wing vertical-take-off-and-landing airplane, NASA TN D-44, 127 pp., Mar. 1960.

The model had two 6-blade dual-rotating propellers that were not interconnected mounted on a wing that could be tilted up to an incidence angle of about 90° for vertical take-off and landing. The investigation included measurements of both the longitudinal and lateral stability and control characteristics in normal-forward-flight, transition, and hovering ranges. Tests in the forward-flight and transition conditions were made at various wing incidences and power conditions. Tests in the hovering condition were made in the presence of the ground. The data are presented without analysis.

From author's summary

5334. Sarsted, G. J., and Coles, A. V., The development and flight testing of helicopters, *J. Roy. Aero. Soc.* **64**, 592, 211–223, Apr. 1960.

Thermodynamics

(See also Revs. 5234, 5387, 5423, 5433, 5435, 5452)

Book—5335. Obert, E. F., Concepts of thermodynamics, New York, McGraw-Hill Book Co., Inc., 1960, xxi + 528 pp., $11.

This is an introductory textbook for engineering students. The emphasis on the physical and mathematical basis of the subject justify the title from the engineer's point of view. The coverage is wider than usual. Such topics as the third law, the Onsager relations, corresponding states, Cartheodory's formulation and the phase rule are covered. There are many problems worked out as well as numerous exercises for the student.

The typography and illustrations are very good. The index is adequate and there is a convenient list of symbols with definitions and a reference to the section in which they are introduced or explained. Reviewer has not made an extensive check for typographical errors but noted that the Bridgman tables did not carry over two minor errors from the original journal version.

It is unusual for a thermodynamics text to discuss units and dimensions in as much detail as this one does, and here the reviewer believes there is some grounds for criticism. The author favors the English engineering system which uses length, time, mass and force as the basis of mechanics, making it necessary to introduce a dimensional quantity which is not an acceleration but is numerically equal to the acceleration of gravity. It is surprising that there is no discussion of the Rayleigh-Riabouchinsky correspondence on temperature. This is, however, a minor defect in an excellent text which can be particularly recommended for individual study. The author has made a remarkable effort to explain matters clearly and in great detail by numerous footnotes, which makes the work especially useful to readers who cannot consult an instructor. The numerous tables of auxilliary data designed to make the work self-contained and the wide coverage of topics make it a very useful reference. W. Squire, USA

5336. Fuks, G. I., On the mathematical formulation of the first principle in technical thermodynamics (in Russian), *Izv. Tomskogo Politekhn. In-ta* **89**, 27–32, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 5949.

Author holds the view that in a number of books on technical thermodynamics a somewhat inaccurate and inadequately expressed concept of the mathematics involved in the first principle of thermodynamics is put forward for the irreversible processes. Emphasis is laid on the fact that if an irreversible process is accomplished then, with the same supply of heat Q and the same general character for the process, a smaller quantitative result for the work done will be obtained than for the work of W_0 in the reversible process. The work W_H of the irreversible process will be $W_H = W_0 - W_n$ (where W_n represents the work which has been converted into heat in consequence of the irreversibility of the process, namely friction and the like). The work so converted induces a corresponding increase in the internal energy of the working body. Therefore the magnitude of the internal energy U_{2H} at the end of the irreversible process will be larger than in the case of the reversible process

$$U_{2H} = U_{20} + AW_n$$

and the first principle of thermodynamics for the irreversible process will take the form of

$$Q = U_{2H} - U_1 + AW_n$$

A critical discussion ensues on the position taken up in various books in the light of the expressed viewpoint of the author.

S. B. Gerasimova

Courtesy Referativnyi Zhurnal, USSR

5337. Hart, E. W., Thermodynamics of inhomogeneous systems, Part 2, *Phys. Rev.* **114**, 1, 27–29, Apr. 1959.

A so-called generalization of the boundary is introduced to render a previous work [AMR **12**(1959), Rev. 6273] more complete. This paper cannot be read without reference to the previous one.

W. C. Orthwein, USA

Book—5338. Wootton, W. R., Steam cycles for nuclear power plant (Nuclear engineering monographs series), New York, Simmons-Boardman, 1958, vii + 66 pp. $2.75.

The book, in its first section, deals with the different steam cycles for gas-cooled, graphite-moderated, nuclear power plants, both of which are already being used as well as others which may be topical in the future. In the second section the equivalents for PWR and BWR are treated but more briefly.

In some excellent appendices (which constitute approximately half of the book and where a large proportion of the book's merits exist), steam-tables, Mollier-diagram and T-S-diagram with practical arithmetical examples are treated, and there the essential parts of steam turbine plants, with arithmetical examples on turbine, heat exchangers and the whole steam cycle, are described.

From the above we conclude that the book gives in an elementary and easily comprehensible way a good appreciation of the most usual principles and an up-to-date review of more advanced theories for steam cycles and components which are included in a nuclear power plant. Even the inexperienced reader will get, with the help of the practical arithmetical examples, the idea of calculation on a large basis and the problems the heat engineer will encounter.

The book is intended for students and is suitable as a first introduction for newly-appointed engineers within the profession. It also fulfills a great need for persons who are working in other branches of nuclear technology who want to get a general insight into this branch. This book is recommended.

E. Olderin, Sweden

5339. Romanenko, P. N., Influence of the cooling of the components in the section of the turbine between the inlet and outlet valve through which the gas passes on the economy of running a gas turbine unit (in Russian), *Nauchn. Trudi Mosk. Lesotekhn. In-ta* no. 9, 7–46, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1384.

An approximate formula is derived which determines the relationship of the internal relative k.p.d. (efficiencies) of the cooling and non-cooling turbines. This is carried out on the assumptions of identical stages of diminution of pressure and relative k.p.d. (efficiency) at each stage and absence of additional hydraulic losses in the cooling stages in comparison with the non-cooling. A value enters this formula for the mean indicator of the polytropy of the expansion process with the removal of heat from the gas n; in order to be able to use the formula it is necessary to know the magnitude of n, for which purpose a preliminary determination is made for the indicator of the polytropy of expansion n_i in the i^{th} circuit. Starting from the equation of thermal equilibrium removed by the cooling element and the heat separating off during the process of polytropic expansion with cooling the author arrives at the following approximate formula

$$n_i = k \frac{ln\varepsilon_u}{ln\varepsilon_u - a_i}$$

where ε_u is the degree of depression of the pressure in the circuit; a_i the magnitude dependent on the parameters of the gas in front of the circuit, the relation of the temperatures of the wall and the gas $\overline{T}_{wi} = T_{wi}/T_i$, and also the hydraulic and constructional characteristics of the stage. The linkage between n and the values n_i is found from the prerequisite that the expansion curve, drawn in conformity with the polytropy principle, should correspond to its maximum extent with the actual process of expansion in the cooling stages. The complex relation thus obtained between n and n_i can be simplified by assuming that in all the circuits or groups of circuits identical values shall be held by T_{wi} and the dimensionless parameters characterizing the hydraulic and constructional properties of the given circuit. Calculations carried out by the proposed procedure showed that the cooling of the elements in the section of the turbine between the inlet and outlet valve through which the gas passes reacts more markedly on its economical working the higher the temperature of the gas and the lower its initial pressure. Consequently in gas turbine installations working on a closed cycle with high absolute pressures of the working body (which hold out special prospects in connection with the development of atomic energy) one cannot expect drops in the k.p.d. (efficiency) because of the cooling of the blades.

V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

5340. Tauber, G. E., Variational principle for transport phenomena, *J. Franklin Inst.* **268**, 3, 175–221, Sept. 1959.

In the case of transport phenomena the fundamental equation de-

termining the distribution function is the Boltzmann equation $L(F) = X$ where L represents the integral operator due to the change of the distribution function by collisions, and X the force due to the external field and temperature gradients. If now the function F is expanded in a series of the form $F = \sum_r a_r \varepsilon^r$, ε being the energy, variations with respect to the coefficients a_r will result in a system of linear equations $\alpha_r = \sum_s dr_s a_s$ where α_r and dr_s can be evaluated from a knowledge of the form of L and X. The various transport coefficients can then be obtained in terms of energy integrals K, which can be expressed (Enskog) in terms of infinite determinants, the elements of which can be evaluated for a given energy-momentum dependence. A generalization of the theory can be achieved by considering the effect of an external field and the presence of lattice vibrations for this case, and the nonequilibrium phenomena distribution can be taken into account. The paper contains a discussion for the cases of magnetic field, lattice vibrations, and interband-scattering, and a combination of any or all of these. The appropriate variational principles are derived and their solution indicated by an application of the Ritz method. Finally it is shown how the transport coefficients can be expressed in terms of infinite determinants, which differ from each other in the number and nature of their matrix elements.

H. Mludek, Germany

5341. Frontas'ev, V. P., and Gusakov, M. Ya., The heat conductivity of certain organic liquids, *Soviet Phys.-Tech. Phys.* **4,** 10, 1171–1177, Apr. 1960. (Translation of *Zh. Tekh. Fiz., SSSR* **29,** 10, 1277–1284, Oct. 1959 by Amer. Inst. Phys., New York, N. Y.)

The results are given of thermal conductivity measurements on 22 organic liquids carried out by the authors using an optical method. A comparison of the results obtained by the authors with those in the literature shows that the known values of thermal conductivities are reliable.

The organic substances benzene, toluene, nitrobenzene acetone, chlorobenzene, bromobenzene, and carbon tetrachloride are recommended as standard liquids for calibrating any apparatus destined to be used in measuring thermal conductivities of liquids.

From authors' summary

5342. Monchick, L., Collision integrals for the exponential repulsive potential, *Physics of Fluids* **2,** 6, 695–700, Nov./Dec. 1959.

Calculations of the collision integrals and scattering cross sections have been made for the simple exponential repulsive potential. Author points out that true potentials should approximate this function for the short interaction distances of importance in high energy collisions, but that results cannot be safely extrapolated beyond range where validity has been checked experimentally. Some coefficients of viscosity for various gases are calculated from the analytic model which agree favorably with calculations of Amdur and Mason based on experimental scattering potentials for temperatures between 1000 and 15,000 °K.

C. F. Hansen, USA

5343. Mason, E. A., Vanderslice, J. T., and Yos, J. M., Transport properties of high-temperature multicomponent gas mixtures, *Physics of Fluids* **2,** 6, 688–694, Nov./Dec. 1959.

The effects of multiple interaction curves and of excitation and charge exchange on the diffusion, thermal diffusion, viscosity, and thermal conductivity of multicomponent gas mixtures have been considered. These effects are important at high temperatures. It has been shown that the formal results of classical kinetic theory are not changed, but that the cross sections or collision integrals must be computed as weighted averages. The results are the same in all Chapman-Enskog approximations. The effect of excitation exchange has also been shown to be of considerable importance in determining the transport properties of mixtures at high temperatures. The method of calculation of the probability of excitation exchange has also been extended to handle cases of multiple interaction curves.

From authors' summary by C. F. Hansen, USA

5344. Cohen, N. B., Correlation formulas and tables of density and some transport properties of equilibrium dissociating air for use in solutions of the boundary-layer equations, NASA TN D-194, 37 pp., Feb. 1960.

From existing tables and charts of thermal properties of equilibrium dissociating air, author obtained empirical formulas for variation of density, and of product of density and viscosity with enthalpy by the method of least squares. For the anomalous behaviors of Prandtl number, Lewis number and a diffusion function with enthalpy, tables are given instead. The pressure ranges from 10^{-4} to 10 atms and enthalpy from 128.7 (540 °F) to 16,930 Btu/lb. Although these functions are appropriate for calculating real-gas equilibrium boundary layer as author claims, they offer no special advantage over existing tables and charts. For instance, the NBS gas tables are readily available in IBM-card form for numerical computation, which is apt to be more accurate.

H.-T. Yang, USA

5345. Herman, R., and Rubin, R. J., Model for vibrational relaxation of diatomic gases behind shock waves, *Physics of Fluids* **2,** 5, 547–550, Sept./Oct. 1959.

The problem of the vibrational relaxation of a system of harmonic oscillators is examined for the case in which the oscillators are in contact with a heat bath whose total heat capacity is finite and whose temperature therefore varies during the relaxation process. An analysis is carried out for processes in which the initial distribution of vibrational energy is a Boltzmann distribution. Application is made to the vibrational relaxation of a diatomic gas behind a shock wave.

From authors' summary

5346. Soloukhin, R. I., Physical investigation of gases by means of shock waves (in Russian) *Uspekhi Fiz. Nauk* **68,** 3, 513–528, June 1959.

Review deals with: choice of method for producing and using shock waves; thermodynamic properties of air and other gases at high temperatures; propagation of shock waves in relaxing gases; investigation of chemical reactions in gases at a shock wave; spectroscopic investigation of the gas state at a shock wave; thermodynamic equilibrium on ionization at a shock wave.

R. F. S. Hearmon

Courtesy of Physics Abstracts

5347. Tykodi, R. J., and Eriksen, T. A., Thermodynamics, stationary states, and steady-rate processes, Part 1: Introduction, and migrational equilibrium in isothermal and monothermal fields; Part 2: Migrational equilibrium in thermal fields; Part 3: The thermocouple revisited; Part 4: Steady monothermal rate processes, *J. Chem. Phys.* **31,** 6, 1506–1525, Dec. 1959.

Authors develop relations for stationary states and steady rate processes employing only first and second law principles plus a statement of the entropy generation in the limit of one flow tending to zero. The aim is to arrive more directly at the migrational equilibrium conditions without resorting to the phenomenological flux-force relations. Part 2 contains the main part of the analysis and is followed by experimental comparison. Authors suggest in Part 3 that a homogeneous thermoelectric effect does not exist. Part 4 adds nothing new.

J. H. Keenan, USA

5348. Merkulov, A. P., Characteristics of and calculations for a vortex refrigerator (in Russian), *Trudi Kuibyshevsk. Aviats. In-ta* no. 6, 73–85, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6188.

An approximate method is given for the calculations for vortex refrigerators. The principle of the calculations is based on the utilization of the equations for the phenomenological thermodynamics with the simultaneous use of a series of experimental results. A detailed account is given of the vortex refrigerator designed and built by the Kuibyshevsk aviation institute which, in the tests made with it, gave the best results. The principal distinguishing feature of the above type of refrigerator from ones previously tested was the rectangular inlet of the jet with no vortex zone in the outlet section and the provision of a rectification device (cross piece) in the vortex zone, which makes it possible to reduce very considerably the length of the latter. The results of experiments on a number of vortex refrigerators are furnished. A diagram is drawn of the generalized characteristics. An example of the calculations for a vortex refrigerator is given together with a comparison of the calculated and experimental results. Yu. A. Lashkov

Courtesy Referativnyi Zhurnal, USSR

5349. Kirenkov, I. I., Metrological features of color pyrometry, *Measurement Techniques* no. 1, 33–39, Mar. 1960. (Translation of *Izmerital'naia Tekhnika, USSR* no. 1, 28–31, Jan. 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

5350. Levin, E. D., A thermocouple for measuring the top layer temperature of the coke mass, *Indust. Lab.* **25,** 4, 503–504, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, 485–486, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5351. Gerthsen, P., Gilsing, J. A. A., and van Tol, M., An automatic dew-point hygrometer using Peltier cooling, *Philips Tech. Rev.* **21,** 7, 196–200, 1959/60.

The most accurate method of measuring the humidity of a gas is to determine the dew point. The cooling required for this purpose can be obtained by utilizing the Peltier effect of a combination of certain semiconductors. A description is given of a dew-point hygrometer based on this principle (it is a variant of an instrument using liquid-air cooling, also described). In this apparatus a silver reflector (5 mm thick, surface area 75 mm^2) is cooled to below the dew point. A beam of light is directed from this reflector on to a cadmium-sulphide photoresistor. When the reflector mists over, the beam is diffusely reflected; the photoresistor therefore receives less light and the photocurrent decreases. The latter controls the current through the Peltier element. The control loop thus formed is in equilibrium when the temperature of the reflector is equal to the dew point. The error in the measurement is less than ½ °C. From authors' summary

5352. Berezin, G. I., A simple and highly sensitive thermocouple battery for the measurement of body surface temperature, *Indust. Lab.* **25,** 4, 502–503, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, 484–485, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5353. Short, W. W., and Sage, B. H., Temperature measurements in a spherical field: transfer coefficients and corrections for thermocouples in boundary flows, *AIChE J.* **6,** 1, 163–167, Mar. 1960.

A study was made of the deviation between the temperature of thermocouple junctions and the temperature of the fluid surrounding them which arises as a result of conduction along the thermocouple leads. Measurements around a ½-in. heated sphere in the plane of the equator normal to an air stream having a velocity of 16 fps were made with a 0.001-in.-diam thermocouple of platinum and platinum rhodium. Air temperatures in the boundary flows of the sphere were predicted from the indications of the thermocouple. The method of prediction employed also determined the heat-transfer coefficients for the thermocouple wire in the boundary layer. These local heat-transfer coefficients are lower than those observed in a uniform stream having a velocity equal to the estimated local velocity in the boundary layer.

From authors' summary by G. J. Nothwang, USA

5354. Sukhov, S. A., Kadlets, S. Ya., and Pavlyuk, G. D., Investigation of electrolytic thermocouples, *Measurements Techniques* no. 2, 121–123, Apr. 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 2, 35–36, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5355. Katys, G. P., Dynamic properties of devices for measuring unstable temperatures, *Measurement Techniques* no. 3, 230–235, May 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 3, 58–62, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5356. Clouston, J. G., Gaydon, A. G., Hurle, I. R., and Glass, I. I., Temperature measurements of shock waves by spectrum-line reversal, Parts 1 and 2, *Proc. Roy. Soc. Lond. (A)* **248,** 1255, 429–444, Dec. 1958; **252,** 1269, 143–155, Sept. 1959.

Time-resolved measurements of temperature in flow of air, N_2, and O_2 following normal shock waves are made by the line-reversal method, where sodium or indium are added as the active impurities. By using a null method, the results are made independent of impurity concentration, and temperature histories are determined to about ±20 °C. Measurements are normally limited to maximum brightness temperature obtainable in the light source used, though somewhat higher temperatures can be measured with some loss in accuracy. Temperatures up to 3600 °K are determined in N_2 using a carbon arc source and indium blue line reversal. Some measurements in A are also made, but the collision processes in the monatomic gas do not keep the sodium in equilibrium so that low temperatures are registered. C. F. Hansen, USA

5357. Katkov, O. M., Apparatus for the simultaneous measurement of the viscosity and electrical conductivity of slags, *Indust. Lab.* **25,** 3, 390–392, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 372–373, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Heat and Mass Transfer

(See also Revs. 4983, 5041, 5139, 5174, 5259, 5262, 5273, 5283, 5341, 5342, 5343, 5344, 5349, 5350, 5352, 5353, 5356, 5425, 5426, 5457, 5462, 5518, 5521, 5522)

5358. Ioffe, I. A., On the stationary temperature distribution in a semi-infinite medium with cylindrical internal heat sources, *Soviet Phys.-Tech. Phys.* **3,** 5, 1011–1015, Jan. 1959. (Translation of *Zh. Tekh. Fiz., SSSR* **28,** 5, May 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author applies the well-known analytical method of superposition of line sources and sinks to obtain the stationary temperature field in a semi-infinite medium containing an endless row of cylindrical heat sources (thin pipes). Solutions are presented in a simple closed form. Temperatures at the medium surface and at the pipe surfaces are calculated. From the analytical solution one can readily obtain the isotherms, as shown in a numerical example. F. T. Adler, USA

5359. Ling, F. T., A quasi-iterative method for computing interface temperature distributions (in English), *ZAMP* **10,** 5, 461–474, Sept. 1959.

Author considers flash temperature problem for semi-infinite body sliding on rectangular contact area protruding slightly above another such body. Starting from known theories, both for stationary and moving heat sources, a singular integral equation of the first kind is set up, under usual assumption of vanishing temperature jump across contact area. Iterative techniques for solving this equation numerically are developed for various ranges of the Peclet number, $R = vl/2a$, where v is the sliding velocity, l the width of the area in the direction of this velocity, and a the thermal diffusivity.

Even in the intermediate range where R is of the order of unity, author shows that two iterations suffice for any practical purpose. In the case $R = 1$, author's result, particularly as regards the maximum flash temperature reached in the contact area, differed only slightly from that obtained according to the approximate technique of Blok [Proc. Gen. Disc. Lubric., Instn. Mech. Engrs., **1**, p. 222; London, 1937].

To arrive at an exact solution, in the form of a series expansion in Mathieu functions, reviewer suggests to introduce confocal coordinates. H. Blok, Holland

5360. Schniewind, J., A heat conduction problem in a composite body (in German), *Forsch. Geb. Ing. Wes.* **25**, 6, 196–198, 1959.

Mathematical treatment is presented of linear flow of heat in a semi-infinite solid consisting of two layers, one extending from $x = 0$ to $x = d$, the other from $x = 0$ to infinity. The solid is initially at constant temperature. From $t = 0$ onward its surface ($x = 0$) is in contact with a fluid having a different temperature. Heat transfer between the surface and the fluid can be described by means of a constant heat-transfer coefficient h.

The solution is obtained by application of the Laplace-transform method. Numerical results are given for various values of $K_1\kappa_2/K_2\kappa_1$ and hd/K_1 (K = thermal conductivity, κ thermal diffusivity, subscripts 1 and 2 refer to the layers in the order mentioned above.) D. A. DeVries, Netherlands

5361. Friedman, A., Free boundary problems for parabolic equations, Parts 1 and 2: Melting of solids; Evaporation or condensation of a liquid drop, *J. Math. Mech.* **8**, 4, 499–517, July 1959; **9**, 1, 19–66, Jan. 1960.

In Part I the author refines a method of L. I. Rubinstein to show existence and uniqueness of solution of Stefan's problem (i.e., of the heat equation in the region $0 < x < x(t)$, where $U[s(t), t] = 0$, $U_x[s(t), t] = -\dot{s}(t)$; $U(0, t)$, $U(x, 0)$ are prescribed, $s(0) > 0$ is assumed). The problem is reduced to a nonlinear integral equation for which solution is obtained for small times, then the solution is extended to large times. In Part II the condensation and evaporation of a liquid drop surrounded by vapor of its own substance is similarly treated. Method of solution utilizes ideas of Banach space, fixed-point theorems, L. Nirenberg's results on maximum principle for parabolic equations, and certain *a priori* bounds which the author establishes. G. Horvay, USA

5362. Broglio, L., Heat conduction in solids at hypersonic speed (in English), AFOSR TN 58 1132 (Univ. Roma, Scu. Ingegneria Aero. SIARgraph 45, ASTIA AD 207 977), 32 pp., Oct. 1958.

By use of a solution which gives the temperature distribution in an arbitrarily shaped body due to an instantaneous heat source, series representations are written for the distribution of temperature and heat flow within the body due to a time-variable and space-variable distribution of heat sources. An equation is obtained by which the coefficients of the temperature series are related uniquely to the corresponding coefficients of the heat flow series—with time as the only independent variable. This latter relation is readily adapted to stepwise integration process whereby the time-dependent temperature distribution can be obtained for a known heat input function. Cases in which temperature-dependent properties are involved can also be treated by this method.

The method is applied to the problem of aerodynamic heating at hypersonic speeds. An exact expression is obtained for the trajectory of a body in the atmosphere, for the case in which gravity and centrifugal forces are neglected. This relation is then used in conjunction with the above heat-conductive analysis to obtain a numerical solution for the timewise temperature variation at the inner and outer surfaces of a thin hollow hemisphere. Unfortunately there is no specification of the assumed flight conditions (i.e., velocity, range, altitude, etc.) used in the calculations.

A. J. Chapman, USA

5363. Merkulov, V. I., Heat exchange in plane laminar flow of a viscous fluid, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 3, 819–822, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Paper deals with the temperature distribution in an infinite two-dimensional steady-state flow of viscous incompressible fluid transmitted by a body kept at constant temperature. The flow region is conformally transformed into the $\phi\psi$ plane ($\phi + i\psi$ the complex velocity potential of the nonrotational flow with the same boundaries and boundary conditions at infinity) and in terms of these generalized coordinates the problem is represented by an integral equation of Fredholm's type. In the case where a boundary-layer approximation can be made it is shown that the problem has a unique solution.

Reviewer remarks that the uniqueness is shown provided that the boundary-layer approximation used is unique.

L. S. Rintel, Israel

5364. Kanter, I. E., Martinek, F., and Ghai, M. L., High temperature heat transfer from gases to cylinders and nozzles, AFOSR TN 59-488 (General Electric Co., Flight Propulsion Lab. Dept.; ASTIA AD 215 841), 128 pp., 1959.

5365. Doraiswamy, L. K., and Patel, N. S., Performance of a pulsed heat exchanger, *J. Sci. Indust. Res., India* **18A**, 11, 522–526, Nov. 1959.

Data are reported on the effect of pulsations on heat-transfer efficiency. Employing three heat exchangers the values for the overall heat-transfer coefficient have been obtained over a wide range of Reynolds numbers and at frequencies of 40, 81 and 160 cycles/min, the pulses being damped to various degrees at each of the frequencies. The results, which show that pulsations can be used to improve heat-transfer coefficients, are discussed in the light of the conflicting data reported in the literature.

From authors' summary

5366. Cess, R. D., and Shaffer, E. C., Laminar heat transfer between parallel plates with an unsymmetrically prescribed heat flux at the walls, *Appl. Scient. Res.* (*A*) **9**, 1, 64–70, 1959.

Paper extends authors' previous work [*Appl. Sci. Res.* (*A*) **8**, p. 339, 1959], which related to symmetrically prescribed heat flux, also for laminar flow. Present solution is worked out to the first four odd eigenvalues and constants, and also includes asymptotic expressions for these quantities. H. Blok, Holland

5367. Teverovskii, B. M., The influence of roughness of the surface on the hydraulic resistance and on convection heat exchange (in Russian), *Izv. Vyssh. Uchebn. Zavedenii Energetika* no. 7, 84–89, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6435.

Experiments were carried out in tubes with artifically given roughness, made by incizing the surface with special drills of triangular metric pattern. The interchangeable experimental section had a diameter of 30 mm and a length of 2 m; the relative roughness of the various sections experimented with varied within the limits of b/r of 0.02 to 0.08. The working medium employed was air. The

tube was heated on its outside surface by condensing steam. The thermal flow was determined by the quantity of the condensate formed, the temperature of the wall was obtained by calculation; measurements were made at the inlet and outlet of the experimental section of the profiles of velocity and temperature of the air. The results of the experiments, which embraced a range of changes of Reynolds number R from 24,000 to 327,000, were analyzed in terms of criteria of similarity. As a result the following formula was proposed for $R > R^*$ (the latter characterizes the beginning of the region of thermal automodelling capacity and is determinable by the relative roughness)

$$N = c\,R, \qquad c = 0.0022\left(1 + 6.865\,\frac{h}{r}\right)$$

Although comparison of the results of various investigators showed satisfactory convergence, the author remarks that because of the large multiplicity of forms of roughness the introduction of the single quality or characteristic of the height of the protuberance can only be accepted for investigation to the first approximation.

V. V. Kirillov

Courtesy Referativnyi Zhurnal, USSR

5368. Nakagawa, Y., Experimental observations of overstable cellular convection, *Proc. Roy. Soc. Lond.* (*A*) **253,** 1273, 212–217, Nov. 1959.

Paper describes experiments on overstable cellular convection occurring in rotating layer of mercury heated from below. A thin layer of water prevented oxidation on top surface. Periodic reversal of convective circulation and hexagonal pattern of cells was observed by tracer movements. Observations confirm Chandrasekhar's theoretical predictions of wave number of cells and characteristic period of oscillatory motions.

From author's summary by R. N. Cox, England

5369. Gershuni, G. Z., and Zhukhovitskii, E. M., Two types of instability in a convection motion between parallel vertical planes (in Russian), *Izv. Vyssh. Uchebn. Zavedenii Fizika* no. 4, 43–47, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6394.

This is an investigation of a problem on the stability of a stationary convection motion between parallel vertical planes heated to various temperatures. This problem has been presented previously and solved in a first approximation by one of the authors [G. Z. Gershuni, *Zh. Tekhn. Fiz.* **23,** no. 10, p. 1838, 1953]. In the present work the problem is solved in a higher approximation. The problem merges with the investigation of a system of two ordinary differential equations for the amplitude of the function for a current φ and a temperature θ of the plane harmonic disturbances of a stationary motion with homogeneous boundary conditions. The parameters are Grashof and Prandtl numbers (G and P), a material surge number k and a complex frequency for the excitation ω. The problem is solved by Galerkin's method. Polynomials are adopted as approximate functions. The authors conclude that the motion being investigated is unstable, and that two types of instability can occur: relative "standing" ($\omega = 0$) and "running" ($\omega \neq 0$) disturbances. With $P < 1.8$ a crisis produces "standing" disturbances. With $P > 1.8$ crises of both types are possible, while with $P > 2.2$ the more dangerous appear to be the "running" disturbances, as they correspond to the lower Grashof critical numbers. The first approximation only indicated instability with $\omega \neq 0$.

V. N. Arkhipov

Courtesy Referativnyi Zhurnal, USSR

5370. Gershuni, G. Z., and Zhukhovitskii, E. M., The closed convective boundary layer, *Soviet Phys.–Doklady* **4,** 1, 102–104, Aug. 1959. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **124,** 2, 298–300, Jan./Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

A horizontal circular cylinder filled with a liquid is heated at one and cooled at the other side. The resulting convective heat transfer and flow of the liquid have been computed assuming that the core rotates as a solid body, the boundary layer has the same thickness for temperature and velocity, the thickness of the boundary layer is uniform and small in comparison with the radius of the cylinder, and the curvature of the boundary layer may be neglected. No experimental verification of the theory has been presented.

J. A. Businger, USA

5371. Schmidt, E., Gravity convection of bodies in the neighborhood of their critical states (in German), Advances in Aeronautical Sciences, Vol. 1 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958), Pergamon Press, 1959, 333–342.

5372. Henshall, B. D., Stagnation-point heat-transfer rate measurements in the unexpanded flow of the NPL hypersonic shock tunnel, Aero. Res. Counc. Lond. Curr. Pap. 468, 8 pp., 1960.

5373. Hoshizaki, H., The effect of shock-generated vorticity, surface slip, and temperature jump on stagnation-point heat-transfer rates, *J. Aero/Space Sci.* **27,** 2, 135–136 (Readers' Forum), Feb. 1960.

5374. Sparrow, E. M., Unsteady stagnation-point heat transfer, NASA TN D-77, 26 pp., Oct. 1959.

Paper gives technically important results for the unsteady heat transfer by forced convection at a stagnation point for steady laminar flow and constant properties of the incompressible fluid. The velocity profiles are approximated in the usual way by polynomials. The first problem solved is the heat transfer for a step change of the wall temperature. Because of the linearity of the energy equation this solution can be generalized by superposition, e.g. for a linearly-varying wall temperature.

Author compares the results of his unsteady heat-transfer solution with the assumption of quasi-steady conditions and shows graphs for Prandtl number 0.7. K. Pohlhausen, USA

5375. Baldwin, B. S., Jr., Application to fluid dynamics of the theory of reversible heat addition, NASA TN D-93, 16 pp., Oct. 1959.

An inviscid flow theory with reversible heat addition such as in radiating or reacting gas flows is studied. In the latter case, however, the fuel mass flow and forces due to it are neglected and only the energy terms due to the presence of fuel are considered. The applicability of this theory of reversible heating to the following types of flow problems is discussed: (1) flow with combustion; (2) flow of a gas not in equilibrium with respect to all degrees of freedom, and (3) radiation absorbed and/or emitted by a flowing gas.

The theory in particular is applied to the underwing heat addition schemes and the performance of such systems is predicted. The results show that underwing combustion may not compare favorably with conventional ramjet engine efficiencies in the Mach number range from 5 to 10. R. E. Bolz, USA

5376. Levey, H. C., Heat transfer in slip flow at low Reynolds number, *J. Fluid Mech.* **6,** 3, 385–391, Oct. 1959.

Author considers case of heat transfer by forced convection from a hot wire in a low Mach number rarified gas stream for a range of small Reynolds numbers. Upon solving appropriate forms of the continuity, momentum, and energy equations, an expression is found for the Nusselt number. The Nusselt number expression is simplified to predict a correct result for continuum flow and a nearly correct result for free-molecule flow. From these observations, author proposes that his Nusselt number expression may be useful for interpolation in the regimes between continuum and free-molecule flow. R. L. Young, USA

5377. Rushton, J. H., Mixing, *Indust. Engng. Chem.* **52,** 6, 543–544 (Unit processes review), June 1960.

5378. Wilke, C. R., Prausnitz, J. M., and Acrivos, Andreas, Mass transfer, *Indust. Engng. Chem.* **52,** 5, 441–446 (Chemical engineering fundamentals review), May 1960.

5379. McCormick, P. Y., Drying, *Indust. Engng. Chem.* **52,** 5, 439–440 (Unit operations review), May 1960.

5380. Leva, M., and Wen, C.-Y., Absorption and humidification, *Indust. Engng. Chem.* **52,** 4, 340–346 (Unit Operations Review), Apr. 1960.

5381. Napolitano, L. G., On an exact solution of laminar mixing of two different gases, *J. Aero/Space Sci.* **27,** 2, 144–145 (Readers' Forum), Feb. 1960.

The flow of two contacting semi-infinite parallel streams of gases is analyzed for the case of constant velocity and differing temperature. Similarity conditions are assumed and thus a single unique equation results for the distribution of temperature across the mixing zone in terms of the time of contact and the gas properties. Examples are given of the mixing of Air–H_2, Air–CH_4 and Air–CO_2, and comparison is made with the simple solution obtained assuming the Lewis number is unity throughout the flow.

W. D. Baines, Canada

5382. Scala, S. M., and Diaconis, N. S., The stagnation-point ablation of Teflon during hypersonic flight, *J. Aero/Space Sci.* **27,** 2, 140–141 (Readers' Forum), Feb. 1960.

5383. McCarter, R. J., and Stutzman, L. F., Transfer resistance and fluid mechanics, *AIChE J.* **5,** 4, 502–505, Dec. 1959.

Evaporation rates from various liquids to air are measured in countercurrent flow of liquid along inside surface of tube. Authors found that if relative velocity is used in gas flow Reynolds number, results are in agreement with previous measurements. A laminar film thickness is calculated from the evaporation measurements and compared to one derived from pipe-flow velocity measurements. Reviewer believes that authors are attempting to describe details of turbulent flow pattern from measurements of bulk flow properties and that comparisons to more detailed studies are not significant.

W. D. Baines, Canada

5384. Litt, M., and Friedlander, S. K., An experimental study of diffusion-controlled reactions in a laminar boundary layer, *AIChE J.* **5,** 4, 483–485, Dec. 1959.

Problem considered is the dissolution rate of plates and cylinders of benzoic and cinnamic acid into dilute aqueous solutions of sodium and potassium hydroxide. Experimental data are compared with the predictions of a theory previously developed by authors [*Chem. Engng. Sci.* **7,** p. 229, 1958]. The mass transfer rate of acid into pure water was found to differ from the calculated rate by about 50%. However, it was found that the predicted ratio of mass transfer with reaction to that without reaction could be brought into agreement with experiment by adjustment of the Schmidt number for sodium hydroxide to a reasonable value.

Reviewer found this paper almost unintelligible. All results are in terms of a Sherwood number which is nowhere defined. In the theory, the location of the reaction zone is apparently an adjustable constant, but no mention is made of how this important quantity is chosen.

L. Mack, USA

5385. Roberts, L., An approximate analysis of unsteady vaporization near the stagnation point of blunt bodies, NASA TN D-41, 31 pp., Sept. 1959.

The protection of objects in high-speed flight through the atmosphere against destruction by aerodynamic heating is an obvious necessity in the launching and recovery of space vehicles. One rather effective method to this end is to coat the object with a shielding material which sublimates during the periods of aerodynamic heating—launching, and especially re-entry. The choice of coating material is dictated in part by sublimation temperature, the maximum allowable temperature of the object to be protected, and the mechanical strength and erosion resistance of the coating at the sublimation temperature. The shielding effect of a coating results from a number of factors: the ability of the coating to absorb some of the heat before the sublimation temperature is reached; the absorption of latent heat of sublimation and sensible heat by the subliming material while an essentially constant temperature is maintained at the surface of the coating; and the decrease of the heat-transfer coefficient to the coating surface due to mass transfer through the boundary layer into the main air stream (transpiration cooling effect).

In this report, author shows that the results of an approximate mathematical analysis of the heat flow into the coating agree quite well with known exact solutions of one-dimensional unsteady heat flow. It is further shown that the steady-state sublimation rate may be predicted from non-steady-state laboratory tests by the use of certain graphs based on this analysis. Only the time required for the coating surface to attain sublimation temperature and one mass-loss measurement during the transient in the temperature profile after the onset of sublimation are needed. Short experiments and thin coatings which are completely consumed in the experiment can thus be used to evaluate the performance of thick coatings under long exposure.

A. W. Gessner, USA

5386. Radbill, J. R., and Kaye, J., Analysis of effects of diffusion of a foreign gas into the laminar boundary layer of a supersonic flow of air in a tube, *J. Aero/Space Sci.* **26,** 9, 602–603 (Readers' Forum), Sept. 1959.

Adiabatic wall temperatures and recovery factors are calculated for pipe flows with an entrance Mach number of 5 and with uniform injection of helium. Predicted values of the recovery factor increase slowly with increasing injection rate and with increasing distance from the tube entrance.

E. L. Knuth, USA

5387. Fleddermann, R. G., Heat transfer to a vaporizing, ablating surface, *J. Aero/Space Sci.* **26,** 9, 604–605 (Readers' Forum), Sept. 1959.

A semiempirical method for predicting the heat-transfer rate to an ablating wall for given wall temperature and given mass-addition rate is presented. Two constants, the latent heat of vaporization and a measure of the reduction of energy-transfer rate due to mass addition, are required. For simple systems, these constants may be estimated from theory; for complicated systems, they may be obtained (using a method outlined in this paper) from experiments.

E. L. Knuth, USA

5388. Thuronyi, G., Annotated bibliography on evapotranspiration, 1956–1959, *Meteorol. Abst.* **10,** 10, 1552–1595, Oct. 1959.

5389. Scott, C. J., Anderson, G. E., and Elgin, D. R., Laminar, transitional and turbulent mass transfer cooling experiments at Mach numbers from 3 to 5, AFOSR TN 59-1305 (Univ. Minn. Inst. Technol., Rosemount Aero. Lab. Res. Rep. 162), 28 pp., Aug. 1959.

A collection of heat-transfer results for porous cones and hemispheres and helium and air as injected gases. Recovery factors, heat-transfer rates, profiles of velocity and concentration, and transition positions are exhibited as functions of injection rate. Significant thermal benefits are shown and discrepancies with theory are noted.

J. R. Baron, USA

5390. Eckert, E. R. G., Mass transfer cooling, a means to protect high speed aircraft, Advances in Aeronautical Sciences, Vol.

1 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 276-286.

5391. Kirenkov, I. I., and Lapina, E. A., A new method for the determination of the effective wavelength of optical and photoelectric brightness pyrometers, *Measurement Techniques* no. 4, 288-291, May 1960. (Translations of *Izmeritel'naia Tekhnika, USSR* no. 4, 37-39, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5392. Wilkins, J. E., Jr., Minimizing the mass of thin radiating fins, *J. Aero/Space Sci.* **27,** 2, 145-146 (Readers' Forum), Feb. 1960.

Author considers problem of heat rejection in space assumed at 0 °F absolute by single fin of minimum mass for given heat flux, base temperature, and material properties. Assumptions of one-dimensional heat flow and constant properties are made.

The optimum fin with contoured profile has about 61% the mass of optimum straight fin and 90% the mass of optimum triangular profile fin. The results for triangular fin agree with those of Nilson and Curry [see following review].

It should be pointed out that author uses a view factor of unity in the radiation equation so that influence of nearby objects or celestial bodies is not included. R. H. Eustis, USA

5393. Nilson, E. N., and Curry, R., The minimum-weight straight fin of triangular profile radiating to space, *J. Aero/Space Sci.* **27,** 2, 146-147 (Readers' Forum), Feb. 1960.

Authors consider problem of heat rejection in space assumed at 0 °F absolute by single fin of minimum mass and of triangular profile. Assumptions of one-dimensional heat flow, unity and view factor, and constant properties are made.

Results agree with those of Wilkins [see preceding review] for triangular fin. R. H. Eustis, USA

5394. Hill, F. B., and Wilhelm, R. H., Radiative and conductive heat transfer in a quiescent gas-solid bed of particles: Theory and experiment, *AIChE J.* **5,** 4, 486-496, Dec. 1959.

Hamaker's treatment [*Philips Res. Repts.* **2,** p. 55 et seq., 1947] of one-dimensional radiant energy transport in a semi-transparent scattering medium has been extended to the cylindrical and spherical cases. The treatment is presented in terms of finite difference equations, corresponding to a subdivision of the bed of particles into concentric shells having a thickness equal to the mean particle diameter. The physical properties of the bed are characterized by the absorptivity, reflectivity and transmissivity of these shells, rather than by the more fundamental material properties of absorption and scattering coefficients. Experimentally, measurements were made of the rate of radial heat flow and of the radial temperature distribution in a long cylinder packed with alumina spheres and operated at temperatures up to 1000 °C. The experiments showed the characteristic radial variation of temperatures in semitransparent cylinders and led to a discussion of the relative magnitudes of the heat fluxes due to radiation and conduction. An estimate of the corresponding absorptivities, reflectivities and transmissivities of the postulated shells was also made on the basis of the heat flow measurements. R. Gardon, USA

5395. Larkin, B., K., and Churchill, S. W., Heat transfer by radiation through porous insulations, *AIChE J.* **5,** 4, 467-474, Dec. 1959.

An analysis is presented of one-dimensional radiant energy transfer in fibrous and foamed insulating materials, in which radiation is simultaneously absorbed, emitted and scattered. This analysis follows the classical lines of Schuster's [*Astrophys. J.* **21,** no. 1, 1905] and is restricted to relatively low temperature levels, at which the radiant flux is a small fraction of the total energy flux. The experimental investigation entailed determination of the absorption and scattering cross sections of several porous insulating materials for black-body radiation at various temperatures between 200 and 800 °F. These data were used to compute the radiant component of the heat flux through the various insulations. Reviewer believes that the utility of this work would have been enhanced if the absorption and scattering coefficients had been measured for monochromatic radiation rather than for black-body radiation. R. Gardon, USA

5396. Tanaka, K., How to calculate temperature distribution or heat flux distribution on a surface in radiation space, *Bull. JSME* **2,** 8, 568-572, Nov. 1959.

Hottel's [McAdams, W. H.: "Heat transmission," 3rd edition, Chap. 4; New York, McGraw-Hill Book Co., 1954] method for computing the radiation exchange within a gas-filled enclosure has been modified to yield an approximation to the temperature distribution over the boundaries. After calculating the problem by Hottel's procedure, a differential area of interest on one of the enclosure surfaces is selected and corrections computed for the geometric exchange factors between the selected point and the other surfaces and the enclosed gas. A heat balance is applied to determine the temperature of the point using the corrections. The reviewer believes this method is useful for simplifying a complicated enclosure problem since the many surfaces of an enclosure may be combined into a few surfaces and a reduced problem solved. However, the procedure has the inherent assumption that the energy fluxes computed from the simplified problem are not affected by the temperature variations calculated in the approximation. Consequently, the magnitude of the corrections must be small or the original solution will be altered significantly. Another assumption used by the author is that of uniform heat flux over a surface, even though local temperature variations are computed by the approximation. Regardless of these conditions, the method is a useful addition to radiation enclosure analysis. J. T. Bevans, USA

5397. Hottel, H. C., and Unger, T. A., The properties of copper oxide-aluminum selective black surface absorber of solar energy, *J. Solar Energy Sci. Engng.* **3,** 3, 10-15, Oct. 1959.

Authors have prepared a careful study of one selective black for the absorption of solar energy, copper oxide on an aluminum substrate. The variables which affect the preparation of this material have been examined systematically and the optimum procedure is presented. The surfaces prepared by the recommended method yield a solar absorptivity of 0.93 and an emissivity of 0.11.

J. T. Bevans, USA

5398. Styrikovich, M. A., Myropolsky, Z. L., Shitzman, M. E., Mostinsky, I. L., Stavrovsky, A. A., and Faktorovich, L. E., The effect of superimposed elements on the beginning of boiling in the steam generating pipes (in Russian), *Teploenergetika* no. 5, 81-87, 1960.

Comparison of experimental data obtained by different authors concerning critical thermal flow arising in the pipes in the process of water boiling. From authors' summary

5399. Labountzov, D. A., Generalized dependencies for heat transfer during bubble boiling of liquids (in Russian), *Teploenergetika* no. 5, 76-81, 1960.

New generalized dependencies are offered for calculation of heat transfer of boiling liquids. From author's summary

5400. Levin, B. I., Heat transfer during condensation of saturated steam on the surface of a bundle of vertical pipes (in Russian), *Teploenergetika* no. 5, 73-75, 1960.

The results of tests conducted on experimental boiler are presented. The analysis of calculation formulas is presented.

From author's summary

5401. Sparrow, E. M., and Gregg, J. L., Laminar condensation heat transfer on a horizontal cylinder, *ASME Trans.* **81**C (*J. Heat Transfer*), 4, 291–296, Nov. 1959.

The continuity, momentum and energy equations are applied to a condensing fluid; the equations are reduced to ordinary differential equations and are solved numerically to give the Nusselt number for a range of Prandtl number from 0.003 to 100. In spite of the fact that the results do not agree with experimental results for low Prandtl numbers, reviewer considers this paper to be an important contribution to the study of heat transfer during condensation.

E. Sunderland, USA

5402. Rachko, V. A., A study of the process of condensation of moving pure steam on arrays of tubes; A study of the effects of the parameters of the steam and the depth of the array of tubes on the process of condensation of moving pure steam, *Soviet Phys.-Tech. Phys.* **3,** 6, 1151–1163, Feb. 1959; **3,** 6, 1164–1172, Feb. 1959. (Translation of *Zh. Tekh. Fiz., USSR* **28,** 6, 1237–1250, June 1958; **28,** 6, 1251–1260, June 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

These two papers present empirical correlations for heat transfer from steam and steam-air mixtures to a bank of staggered tubes. Several tube bank arrangements are investigated and the coefficients for individual tubes at several locations within a bank were also measured showing, as in convection, an improvement and maximum at the second to third row. There is not enough information and data to permit investigation for other correlations. A separate correlation is given for each tube bank but there are differences to warn that all array factors are not known and that the correlations may be specific to the test unit. However the information on the effects of vapor velocity, air content, tube position and array is useful.

A. C. Mueller, USA

5403. Zozulya, M. V., The influence of the viscosity of the condensate on heat emission when steam is condensing (in Ukrainian), *Dop. Akad. Nauk URSR* no. 3, 272–275, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6439.

A scrutiny of the relations $\gamma = f(t)$, $\lambda = f(t)$, $\mu = f(t)$ leads to the conclusion that in deducing the equation for the determination of the coefficient of heat emission α_1 the most important consideration is taking account of the viscosity in relation to a film's thickness, more especially in cases of condensation of viscous matter. The adoption of the concrete form for the relation $\mu = f(t)$ enabled a more precise equation to be obtained for the determination of α_1, which agreed satisfactorily with the experimental data for the condensation of the vapor of a highly viscous substance—glycerine.

From author's summary

Courtesy Referativnyi Zhurnal, USSR

5404. Gilmour, C. H., Application of heat exchangers in chemical plants, *Indust. Engng. Chem.* **52,** 6, 465–467, June 1960.

5405. Morton, D. S., Thermal design of heat exchangers, *Indust. Engng. Chem.* **52,** 6, 474–478, June 1960.

5406. Weir, C. D., Heat exchange in a self-jacketed fluid, *Engineer* **209,** 5440, 723–725, Apr. 1960.

An interesting and unusual application of the theory of heat exchangers occurs in the case where a fluid is losing heat to the surroundings through a jacket provided by itself. This arrangement is sometimes adopted, for example, in flow calorimeters where it is desired to restrict as far as possible the "heat leak" from the measuring section. In the case of flow calorimeters, the measuring stations would be situated in the inmost pass in each case. Though self-jacketing is a not uncommon device, the equations governing the temperature distribution in the system, and therefore the heat loss, do not appear to have been given in the literature. In the single-jacket case the problem is similar to the determination of the temperature distribution in a single-pass shell and tube exchanger and to that of heat exchange between three fluids. The former has been treated by Nesselmann and the latter by Morley. The problem is also analogous to the treatment of the two-tube pass, single-shell-pass heat exchanger analyzed by Underwood. The solution of the problem in the case of a double jacket is more cumbersome but presents no essentially new features; an approximate solution has been obtained for this case.

From author's summary

5407. Mennicke, U., Thermal properties of plate heat exchangers for different arrangements (in German), *Kältetechnik* **11,** 6, 162–167, June 1959.

There exists a definite relation between the number of transfer units and the effectiveness of a definite type of heat exchanger, at given heat-capacity ratio. This relation is primary. But some authors prefer to compare the effectiveness of given heat exchanger to that of a certain standard type for same number of transfer units, while others (like present author), compare the number of transfer units for same effectiveness. This is an erroneous comparison. Author's treatment is primitive, often erroneous. Results are a few correct calculations for multipass-counterflow exchanger.

L. S. Dzung, Switzerland

5408. Veinberg, B., Thermal and hydraulic calculations of heat exchange apparatus (in Russian), *Kholodil'n. Tekhnika* no. 4, 33–38, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6450.

A graphoanalytical method is proposed for the calculations of heat removals, the basis of the method being the assumption that the difference of the temperatures in the apparatus for separate thermal resistances shall be proportional to their magnitudes. The calculations were made for the inner surface of the tubes. Calculations were made for the condenser, the evaporator and the condenser-evaporator of a refrigerating machine. The principal method available to increase the efficiency of heat removal is by enlarging the ratio of the outer surface to the inner by means of fitting fins. If tubes of small diameter are in question, heat removal can be improved by using organic heat carriers. It is not always expedient to raise the heat removal capacity by increasing the speed of the motion of the heat carrier inside the tubes, as this results in a sharp rise in pressure loss and waste of working power in the pump.

The procedure for making hydraulic calculations for the apparatus is described, utilizing a dimensionless criterion characterizing the geometrical proportions of the apparatus. This criterion shows the relation of the length of travel of the heat carrier in the apparatus to the hydraulic radius of the tube. The formulas put forward make it evident that with decrease in the diameter of the tubes there is a proportional decrease in the length of travel of the heat carrier and a corresponding decrease in the number of circuits made by the heat carrier in the apparatus. In this process the form of the caps is simplified and there is a reduction of pressure loss due to local resistances in the lids. At the same time the main pressure losses, i.e., losses due to friction, hardly change. Increasing the velocity is only effective in the region of a marked change in the coefficient of heat transfer, because with increase of the velocity the increase of the coefficient is retarded while the loss of pressure rapidly gets larger. In order to reduce the loss of pressure in the pipe system, the height of the column of liquid raised by the pump and the power imparted to the pump demand heat carriers of small volume. Choice of heat carriers of large volume is justified if the basic losses of pressure occur in the apparatus itself (short pipe systems).

B. I. Bakum

Courtesy Referativnyi Zhurnal, USSR

5409. Dement'ev, V. M., Aerodynamics of a boiling layer (in Russian), *Sb. Statei Nauchn. Stud. O-va Mosk. Energ. In-ta* 167–178, 1953; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6522.

Results are discussed of the experimental determination of the resistance to the flow of cold air through a layer made up of various kinds of solid fuels with different sizes for the pieces. The experiments were carried out in the laboratory of the OPT MEI. A description is given of the experimental plant and graphs are furnished.

$$p = f(\omega), \qquad \lg F = f\left[\lg\left(\frac{\gamma_T}{\gamma_b}\right)^{5.45} R^{0.182}\right]$$

$$\omega_1 = f(d), \qquad p = f(b), \qquad \frac{b}{b_0} = f\left(\frac{\omega}{\omega_1}\right)$$

Here p is the fall of pressure in the layer in mm (water column); ω is the velocity of the flow of the air, referred to the full section of the experimental tube; ω_1 is the velocity corresponding to the beginning of the boiling state; F is Froude's number ($F = g\,d/\omega^2$), d is the hydraulic diameter corresponding to the mean size of the lumps of fuel in the layer expressed in mm; b is the height of the layer of fuel heaped in the small column; R is Reynolds criterion; ν is the kinematic viscosity of the air; γ_T, γ_b are the specific weights of the fuel and of the air respectively. An equation is given for boiling

$$F = \frac{6.51 \times 10^{16}}{R^{0.182}\,(\gamma T/\gamma b)^{5.45}}$$

The equation for the resistance of the boiling layer

$$p = k\,\gamma_H\,b - \Delta P_0$$

The equation for the height of the boiling layer

$$b = -\frac{0.089a}{0.133 - \omega/\gamma_T^{\frac{1}{3}} d^{0.63}}\, b_{pl}$$

P. I. Povarin

Courtesy Referativnyi Zhurnal, USSR

5410. Brown, J. R., Design, calibration and analysis of a helium concentration meter, AFOSR TN 60-39 (Mass. Inst. Technol., Naval Supersonic Lab. TR 416), 25 pp., Dec. 1959.

The mass-transfer investigation at the Naval Supersonic Laboratory is concerned with the consequences of binary-mixture flow in the high-speed boundary layer. Measurement of the boundary-layer composition using a sound-speed concentration meter is an important part of the program.

This report concerns the design, calibration, and analysis of a helium concentration meter. It consists of the theory of operation and methods of calibration discussed in Kenneth A. Peterson's thesis as well as the analysis and operational results obtained from a redesigned instrument. From author's summary

5411. Golde, H., A simple cylindrical apparatus for the measurement of the thermal conductivity of liquids (in German), *Feingerätetechnik* **8**, 8, 376-380, Aug. 1959.

The apparatus consists of concentric copper cylinders with the center cylinder electrically heated and the outer cylinder water cooled. No guard heating is used to eliminate heat losses and it is necessary to calibrate the apparatus with liquids of known thermal conductivity. The accuracy obtained is about ± 2%. The advantages of the system are that measurements can be made quickly over the temperature range from 20° to 80°C, and the calculation of the thermal conductivity from the data is easy.

R. V. Dunkle, Australia

5412. Vargaftik, N. B., and Oleshchuk, O. N., Experimental investigation of the heat conduction of water (in Russian), *Teploenergetika* **6**, 10, 70-74, 1959. (Translation by M. D. Friedman, Inc., P. O. Box 35, West Newton 65, Mass., V-138, 7 pp.)

The thermal conductivity of water has been measured in the temperature range 20°C to 350°C using the hot-wire technique which careful construction of the apparatus made suitable for absolute measurement. Temperature differences were sufficiently small for convection to be negligible. The final results are consistent with previous measurements and are presented in tabular form.

A. A. Townsend, England

Combustion

(See also Revs. 5356, 5375, 5396, 5438, 5456)

Book—5413. Semenov, N. N., Some problems in chemical kinetics and reactivity, Vol. 2 (translated from the Russian by M. Boudart), Princeton, N. J., Princeton University Press, 1959, 331 pp. $4.50. (Paperbound)

A translation of Part III "Kinetics of chain reactions" and Part IV "Branched chain reactions and thermal explosions" of a monograph by one of the most distinguished authorities in this field. The number of chemical reactions which are known to occur by chain processes are now many times greater than in 1935 when the author completed his classic work on this subject. This monograph appears, from the latest references cited, to have been completed in 1957, although the appendices contain some later references.

Part III deals with the problem of deciding whether or not a reaction is proceeding via a chain process. A number of examples of reactions of simple organic molecules are considered in detail. Although it is clearly the intention of the author to present a consistent methodology for the elucidation of reaction mechanism, this is inevitably made difficult by the amount of detail introduced. This part is likely to be of most interest to chemical kineticists, some of whom may feel that the treatment of the experimental data available is partial to one particular viewpoint.

Part IV deals with the slow combustion and ignition phenomena of a number of simple gaseous fuel molecules and with the oxidation of liquid hydrocarbons. It commences with chapters on the theory of thermal explosion and on chain ignition, and discusses the oxidation of phosphorus, carbon disulphide, etc. The hydrogen/oxygen reaction is discussed in considerable detail in Chapter X. The chapters on the oxidation of hydrocarbons are especially noteworthy for the number of references to the recent Russian literature on these subjects.

It appears to be an excellent translation and a very worthwhile book for those specializing in the chemical kinetics of combustion reactions. G. K. Adams, England

5414. Friedman, R., and Nugent, R. G., Flame structure studies—Part IV: Pre-mixed carbon monoxide combustion, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28-Sept. 3, 1958; New York, Academic Press, 1959, 311-316.

In the present study temperature and composition traverses have been made in lean carbon monoxide-oxygen flames with small proportions of added hydrogen or water vapor. A large excess of oxygen, rather than air, has been used to dilute the flame to temperatures sufficiently low to permit traversing because the mass 28 of N_2 coincides with that of CO, interfering with mass-spectrometric analysis. From authors' summary

5415. Gordon, A. S., Smith, S. R., and McNesby, J. R., Study of the chemistry of diffusion flames, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28-Sept. 3, 1958; New York, Academic Press, 1959, 317-324.

5416. Fine, B. D., Chemical sampling downstream of lean, flat hydrogen and propane flames, NASA TN D-198, 25 pp., Dec. 1959.

Hydrogen and propane were burned with air and oxygen-argon mixture in flat flames on porous block burners. Products after

flame were sampled along axis using quartz probe and gas chromatography. Results showed CO and H_2 to occur in large excess of equilibrium amount, decaying with distance from flame. Decay is initially nonlinear but settles to a steady decay rate which increases with flame temperature and is roughly proportional to the oxygen concentration and square root of pressure. Author concludes that water-gas equilibrium is maintained and that decay after propane flames occurs by a recombination reaction involving hydrogen, although some indication of the reaction involving carbon monoxide was sometimes found.

D. G. Stewart, Australia

5417. Cassel, H. M., and Liebman, I., The cooperative mechanism in the ignition of dust dispersions, *Combustion and Flame* **3,** 4, 467–475, Dec. 1959.

Data is reported on gas temperatures required to produce ignition of magnesium and magnesium-aluminum alloy particles of 10–80 micron diameter (apparently at atmospheric pressure). Results for single and for clouds of particles are compared. It is found that ignition temperatures in clouds are lower than for single particles: that ignition temperatures increase with decreasing particle size, except at high particle concentration, where the reverse is true.

Ignition temperatures were measured by injecting the metal particles into a high-temperature, controlled atmosphere furnace. The experimental techniques seem to be highly developed. The principal engineering value of the work is probably in jet propulsion, flame-spraying and the torch-cutting applications. Of particular interest in rocket propulsion is the difficulty encountered by the authors in igniting aluminum particles. Data at higher pressures would be interesting for this application.

E. W. Price, USA

5418. Gray, P., and Harper, M. J., The thermal theory of induction periods and ignition delays, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 425–430.

An approximate form of the heat equation with an Arrhenius-type energy source term is solved for a uniformly heated medium. Ignition delays are inferred from this solution in which reactant consumption has been neglected. Temperature-time histories agree qualitatively with those found earlier by Rice.

The induction period for an adiabatic, exothermically reacting system is first determined from the exact differential equation. Solutions are then found for forms of the equation employing either exponential or quadratic approximations to the nonlinear Arrhenius term. Fortunately, the valid range of the approximations embraces all values of interest, and the three results of induction period agree well in a numerical example.

A. Q. Eschenroeder, USA

5419. Levin, V. Ya., Some problems on pulsating combustion in connection with the problem of the pulsating turbine (in Russian), *Sb. Nauch. Trudi Belorussk. Politekhn. In-ta* no. 56, 316–332, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6207.

An integration for the expressions for the determination of the principle of the change of pressure with time is put forward and also for the determination of the relation of the specific volume to the pressure in the combustion period in the combustion chamber of a pulsating turbine. As an exact integration results in somewhat unwieldy figures, the author, by adopting the method of resolutions in series, obtains approximate but simpler (in form) relationships. In particular, the relation of the increase in pressure with time is obtained in linear form on the assumption of the operation of the linear principle of the separation of heat with time in the combustion chamber of the pulsating turbine. Formulas are derived for the determination of the magnitude of the impulse of the gas stream emerging from the combustion chamber of the pulsating turbine. The determination is made by the summation of the impulses during the scavenging, combustion and exhaust periods. The calculations were made on the assumption that the flow from the jet was either supercritical or transcritical.

A. I. Loshkarev
Courtesy Referativnyi Zhurnal, USSR

5420. Salamandra, G. D., Bazhenova, T. V., and Naboko, I. M., The formation of a detonation wave during the combustion of gas in pipes, *Soviet Phys.–Tech. Phys.* **4,** 11, 1244–1249, May 1960. (Translation of *Zh. Tekh. Fiz., SSSR* **29,** 11, 1354–1359, Nov. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

In a long pipe, a detonation wave is formed as a result of the interaction of the flame front with a series of shock waves, formed in front of the flame front in the predetonation stage.

During the predetonation period, the shape of the flame front undergoes the following changes: (a) in the initial stage of flame propagation, immediately following the ignition of the mixture, the flame front at the closed end of the chamber has a meniscus-like shape, and there is little change in this shape during the entire duration of the initial stage of propagation; (b) during the stage characterized by a retardation of the flame front, the flames assume a characteristic tulip-like shape, testifying to the origin, in front of the flame front, of a gas stream directed toward the flame front; (c) in the stage following the retardation stage, the spread of the flames is characterized by a significant increase in the flame surface area, which leads to an increase in the velocity of propagation of the flames. A series of shock waves is formed in front of the flame front, which creates an accelerating gas stream in front of the flame front, and also raises the temperature of the fresh gas; and (d) in the stage immediately preceding the transition from slow burning to detonation, the surface of the flame front decreases. A long comet-like tail spreads out behind the front; in this tail the fire is burning itself out.

In this stage of flame propagation, the shock wave arising in front of the flame front exerts an especially strong influence upon the flame front. The shock wave and the flame front constitute a single complex, moving with a single speed.

From authors' summary

5421. Salamandra, G. D., and Sevast'yanova, I. K., The interaction of weak shock waves with the flame front, *Soviet Phys.–Tech. Phys.* **4,** 11, 1250–1257, May 1960. (Translation of *Zh. Tekh. Fiz., SSSR* **29,** 11, 1360–1367, Nov. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Authors have found experimentally the dependence of the distance between the ignition point and the point where the shock wave is formed upon the composition and initial pressure of the burning mixture during the combustion of explosive mixtures in a pipe that is closed at both ends.

They have investigated the interaction of weak shock waves with the flame front. It is shown that a detonation wave may arise during the interaction of the flame front with a weak shock wave, formed in the initial stage of the flame propagation, or it may also arise as the result of the spread of the flames through a medium which has already been prepared by shock waves, formed in the predetonation stage of the flame propagation. The transition from slow burning to detonation may occur as the result of selfignition of the combustion process brought about by a shock wave which has been reflected from the end of the tube.

From authors' summary

5422. Vlasov, K. P., and Kokushkin, N. V., On errors in measuring the flame temperature in a stream by using thermocouples (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 137–141, 1957. (Translation by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., V–128, 9 pp.)

An investigation has been made of the measurements of the gas temperature in a flame during the combustion of a benzo-air mixture

in a turbulent stream by the gas analysis method and by thermocouples. A comparison of the temperatures obtained by these two methods shows that the thermocouple yields elevated values of the temperature in comparison with the mean temperature in the majority of cases. From authors' summary

5423. Rossler, F., Distribution temperature of sooty flames (in German), *Ann. Phys.* **4,** 6/8, 396–422, 1959.

Author first establishes the relation between absorption coefficients and the wavelengths of amyl-acetate flame by a 3-term approximation. From that, the relation between the true thermodynamic temperature and the observable color temperature or the black-body temperature is formulated and presented in nomographs. Other flame types can be included by changing the parameters of the equation for the absorption coefficients.

L. S. Dzung, Switzerland

5424. Ullrich, H., Flow processes in turbulent burners with controllable whirl and with free jets symmetrical to the rotational axis (in German), *Brennstoff-Wärme-Kraft* **12,** 3, 114–117, Mar. 1960.

After explaining the general requirements for burners for boiler furnaces, the design of a turbulent symmetrical flow burner is described where the turbulence of the primary air can be modified through the axial movement within a conical ring containing a row of stationary blades. If the behavior of symmetrical jets leaving cylindrical or conical annular nozzle with or without turbulence is considered as being frictionless this results in a straight flow of the individual particles. If jet and surroundings consist of the same medium the exchange of momentum results in a flow towards the jet. If this flow is locally obstructed, eddies with negative pressures are created which may cause a decisive modification of the whole flow pattern. Once the whirlfree flow from an annular nozzle has concentrated into a full jet it is possible to define the flow pattern analytically at sufficient distance from the nozzle exit. Annular jets are possible only where the burner exit is fitted with radial vanes from which the wakes necessary for stabilizing the annular jet extend downstream. A wall jet is obtained through direction of the flow toward the wall. The stability regions for full, ring and wall jets are described. From author's summary

5425. Spalding, D. B., The theory of burning of solid and liquid propellants, *Combustion and Flame* **4,** 1, 59–76, May 1960.

Author presents an interesting theoretical treatment of the steady, plane one-dimensional system in which the process A → B occurs at a solid or liquid surface (e.g., vaporization, or exothermic or endothermic surface reaction) and the exothermic reaction B → C occurs in the gaseous phase. Consideration is restricted to the two limiting cases in which the surface process is one of equilibrium or one involving an unopposed reaction. The procedure involves the use of author's centroid rule for laminar flames, for which some empirical justification exists in the purely gaseous case but none yet exists for the present case in which there is a condensed phase at the cold boundary. The results, which are applicable to double-base propellants, liquid monopropellants, and ammonium perchlorate deflagration, include a graphical method for computing burning velocities and a demonstration that, for some (but not all) systems, radiative heat loss from the propellant surface may produce both low pressure and high pressure burning limits. Also included is a proof of the fact that in this system, when the Lewis number is unity, the total enthalpy remains constant throughout the gas even though the heat capacity, thermal conductivity, and diffusion coefficient may vary with both temperature and concentration.

Reviewer believes that numerical results and comparisons with experiments, such as those given for a similar model by W. Nachbar, Lockheed Missiles and Space Division Technical Note LMSD-288168, Sunnyvale, Calif., Sept. 1959, would enhance the value of the paper. F. A. Williams, USA

5426. Rallis, C. J., Mean temperature of burnt gases, *Combustion and Flame* **3,** 3, 419–420 (Letter to the Editors), Sept. 1959. See AMR **13**(1960), Rev. 1991.

5427. Dorsch, R. G., Allen, H., Jr., and Dryer, M., Investigation of aerodynamic effects of external combustion below flat-plate model in 10- by 10-foot wind tunnel at Mach 2.4, NASA TN D-282, 25 pp., Apr. 1960.

Heat was added directly to the supersonic airstream by external combustion of aluminum borohydride. Lift forces of 55 to 60 pounds per square foot were generated over the first foot of chord of the model at a static temperature of 259 R and a pressure altitude of 62,000 feet. The pressure data are compared with previously reported small-tunnel results in order to obtain an appraisal of possible tunnel effects encountered in the small-tunnel tests. Good agreement was obtained for the shorter-chord small-tunnel models, but the longer-chord small-tunnel models were found to have spurious pressure increases at large distances downstream from the fuel orifices. From authors' summary

5428. Yakubov, G. V., A generalization of the aerodynamic principles involved in cyclone chambers (in Russian), *Izv. Akad. Nauk KazSSR, Ser. Energ.* no. 1 (12), 105–119, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1357.

Author determines the criteria from the aerodynamic similarity of cyclone combustion chambers based on the equations of motion. By making use of the results of experimental investigations on cyclone chambers, carried out by various authors, himself included, the author determines the concrete form of a number of criterial relationships. In particular it was shown that the basic criteria determining the character of the flow in a cyclone chamber appear to be the relation of the sectional area of the outlet opening, the relation of the length of the chamber and its diameter to the relation of the mean absolute temperatures of the gases when leaving the chamber and when entering it. The relations so found enable determinations to be made, with an accuracy of ±10%, for the pressure at the inlet into the cyclone (both for the cold chamber model and for the working cyclone combustion chamber) and for the maximum magnitude of the tangential component of velocity on the internal section of the outlet nozzle (for the cold model).

A. S. Ginevskii
Courtesy Referativnyi Zhurnal, USSR

5429. Bittker, D. A., and Brokaw, R. S., Estimate of chemical space heating rates in gas-phase combustion with application to rocket propellants, *ARS J.* **30,** 2, 179–185, Feb. 1960.

This paper presents a simple, approximate method for calculating maximum chemical space-heating rates in combustion processes. Calculations are made by employing the fundamental physical and chemical properties of the combustion mixture. The results represent the theoretical maximum possible heat-release rate to be expected from a unit volume of a reacting fuel-oxidant mixture. An important purpose of this work is the application of the method to several rocket-propellant combinations. Comparison of the results with estimated heat-release rates for the same propellants in experimental rocket engines shows that the latter are several orders of magnitude less than the calculated maximum chemical rate for a given propellant.

From authors' summary by D. G. Shepherd, USA

5430. Williams, F. A., Theory of the burning of monopropellant droplets, *Combustion and Flame* **3,** 4, 529–544, Dec. 1959.

The steady-state burning of a single liquid monopropellant droplet in an infinite inert atmosphere is considered in detail, including allowance for thermal conduction, diffusion, and chemical kinetic effects. Simplified forms of the governing equations are developed, and theoretical predictions are compared with experimental results. E. W. Price, USA

5431. Clark, B. J., Propellant vaporization as a criterion for rocket-engine design: experimental effect of combustor length, throat diameter, injection velocity, and pressure on rocket combustor efficiency, NASA TN D-258, 27 pp., Apr. 1960.

The combustion efficiency of a heptane-oxygen rocket combustor was measured for various combustor lengths, contraction ratios, combustor pressures, and injection velocities of the heptane. Efficiency increased generally with injection velocity, pressure, combustor length, and contraction ratio, except at some of the lower contraction ratios and injection velocities. From the experimental data and analytical vaporization-rate calculations, apparent drop sizes were calculated. These sizes correlate the data well and show similar trends and are in the same range as drop sizes measured under cold-flow conditions.

From author's summary

5432. Crocco, L., Grey, J., and Harrje, D. T., Theory of liquid propellant rocket combustion instability and its experimental verification, *ARS J.* **30,** 2, 159–168, Feb. 1960.

A straightforward theoretical formulation of the longitudinal high frequency rocket stability criteria is presented. Based on Crocco's sensitive combustion-time-lag theory, the derivation is considerably simpler, although somewhat less rigorous, than previously published detailed treatments. A series of rocket motor experiments is described, demonstrating that there exists an upper limit to the chamber length at which each mode of longitudinal high frequency pressure oscillations will occur, and that this limit is accurately predicted by the theory over a wide range of mixture ratios on two different injectors. The method used to compare experimental results with the theoretical stability limit predictions (including a simple experimental technique for determination of the sensitive time lag) is described.

From authors' summary by D. G. Shepherd, USA

Prime Movers and Propulsion Devices

(See also Revs. 5311, 5375, 5425, 5429, 5431, 5432, 5482, 5483, 5484)

Book—5433. Taylor, C. F., The internal-combustion engine in theory and practice, Vol. 1, Thermodynamics, fluid flow, performance, New York, John Wiley & Sons, Inc., 1960, x + 574 pp. + charts. $16.

The first of a two-volume work, this book deals broadly with the thermodynamic, fluid-flow and performance aspects of internal combustion engines. There are 13 chapters. Chapter 1 contains introductory material. Chapter 2 discusses ideal air cycles, which are closed cycles assuming perfect gas and no chemical reaction. Although the value of air cycles to engine analysis can be questioned, the chapter contains some generalized air-cycle data which can be quite useful if applied with intelligence and ingenuity. The thermodynamics of fuel-air mixtures, combustion reaction and products of combustion are discussed in Chapter 3. Included are four Mollier charts which should prove adequate for all conventional calculations on ideal piston-engine and gas-turbine cycles. Chapter 4 is concerned with ideal fuel-air cycles, which are open cycles based on the Mollier charts presented in Chapter 3. The generalized characteristics of constant-volume and limited-pressure fuel-air cycles are extremely valuable. The concept of the "equivalent fuel-air cycle" provides a powerful tool for quantitatively comparing the performance of an actual cycle with the ideal case. In chapter 5, actual spark-ignition and compression-ignition engine cycles are examined, and the sources of departure of actual cycles from ideal cycles are analyzed in detail.

Chapters 6 and 7 are concerned with the air capacity of the four-stroke and two-stroke engines. These are perhaps the most outstanding chapters of the book. Much use is made of dimensional analysis. The treatment is ingenious and comprehensive.

Chapter 8 on heat losses and Chapter 9 on lubrication, friction and wear likewise make full use of dimensional analysis. Much generalized data of value to designers are presented.

Chapters 10 through 13 deal broadly with performance analysis of compressors, exhaust turbines, and of unsupercharged and supercharged engines. The effect of cylinder size on engine performance is discussed at length. Extensive use is made of performance maps, which present the generalized performance characteristics of various engine types.

In a broad sense, this volume is the outgrowth of "The internal combustion engine" by the author and E. S. Taylor, first published in 1938. The distinguishing feature of this volume is that it is more sophisticated and exhaustive, and provides a sound quantitative basis for engine performance analysis.

The book is unique in two respects. First, it is not a superficial treatment of thermodynamics followed by a loose discussion of the other topics (as is so commonly the case), but a coherent treatise devoted to a rigorous analysis of a complex engineering subject. Secondly, it is not a digest of open literature; much of the material has been developed through years of extensive research at MIT by the author and his associates. Considering the breadth of scope and depth of treatment, this record is most impressive.

P. M. Ku, USA

Book—5434. Jante, A., and Hofmann, K., Internal combustion engines and automotive technology, Vol. 2 [Uber Verbrennungsmotoren und Kraftfahrwesen, Band 2], Berlin, VEB Verlag Technik, 1959, 740 pp.

This is the second volume of reports on the research activities of the East German Institute for Internal Combustion Engines and Automotive Vehicles, which is part of the Dresden Institute of Technology. It comprises 37 papers, 25 of which treat engine problems, and 12 vehicle problems. The authors are the director and staff members of the Institute, but the work of advanced engineering students specializing in automotive engineering is also widely utilized. The research projects are selected by consultation with the East German automotive industry, thus insuring the practical utility and usability of the chosen subjects. The reports on engines deal first with general problems, such as valve gear, wear effects, cam design for smooth acceleration of valve, measurement of radial pressure of piston rings, thermodynamic analysis of combustion and of indicator diagrams, and phenomena of crank case scavenging in two-cycle engines.

Then several reports deal with diesel engine problems, such as injection pump and nozzle design, precombustion chambers, governing, rotary valve for two-cycle engine exhaust and charging, and an instrument—termed the cell-wheel—for measuring the rate of discharge of an injection system and results obtained with it. Reports on Otto-cycle engines deal with methods of improving the part-load economy by throttling, by rejecting part of the charge, and by varying the compression ratio; several reports treat carburetor problems. The reports on vehicles deal with frame design by model tests, investigations on clutches and hydraulic couplings, and adapting the engine characteristics to those of the vehicle. The cars exhibited at the Paris show are evaluated as regards safety features, driver's visibility, springing (air spring of Citroen car), and body design.

Each report is logically organized, first stating the problem and reviewing previous work on it (in which, however, foreign literature, particularly American, could be given more attention); then the theory is discussed, and experimental equipment and method explained; finally the results are stated in tabular or graphical form. The book reflects well the present status of automotive re-

search and thinking in the German Democratic Republic, and it can be studied with profit by research and development engineers working in this field. K. J. DeJuhasz, USA

5435. Nagao, F., Shimamoto, Y., Obayashi, H., and Kurata, T., Effect of crankcase volume on the delivery ratio of a crankcase-scavenged two-cycle engine, *Bull. JSME* **2,** 8, 578–583, Nov. 1959.

In order to increase the delivery ratio and the scavenge pressure in a crankcase-scavenged two-cycle engine, the crankcase volume must be made as small as possible, subject to constructional difficulties. On the other hand, the delivery ratio is considerably affected by pressure fluctuations in the exhaust and inlet systems.

The authors experimentally investigated the effects of the crankcase volume and of the exhaust and inlet systems on the delivery ratio. It was confirmed that the drop in the delivery ratio caused by the increase in the crankcase volume could within limits be compensated by tuning the exhaust and induction pipes. They also found the delivery ratio could be improved greatly by properly tuning exhaust and induction pipes.

From authors' summary by W. Hitschfeld, England

5436. Hagen, H., Consideration in the design of ramjets (in German), *Z. Flugwiss.* **8,** 1, 17–22, Jan. 1960.

Based upon the knowledge of the losses occurring in a ramjet, diagrams are presented with regard to the conditions which are important for the intake and the flow in the combustion chamber; from these diagrams conclusions can be drawn concerning the dependence of engine data on flight Mach number, pressure recovery and operating temperature. Possibilities of adapting a ramjet to variable operating conditions are discussed. By means of an example a comparison between some methods of regulation is given. Data of already constructed ramjets are given. The author refers to the possibility of combining ramjets with other propulsive units.

From author's summary

5437. Rastogi, R. P., and Pandya, T. P., Composition of reaction mixture flowing through rocket nozzle, *ARS J.* **30,** 1, 63–64 (Tech. Notes), Jan. 1960.

A simple procedure is developed which permits the prediction of near-frozen or near-equilibrium flow in rocket nozzles. It is found that the reaction $2\,NO \rightleftarrows N_2 + O_2$ in aniline-nitric acid rocket motors is nearly frozen at the chamber exit, in agreement with the earlier finding of Penner. The recent data on the supersonic flow of N_2O_4 in de Laval nozzles are examined. The predicted composition agrees satisfactorily with the experimental value at the nozzle exit.

From authors' summary

5438. Goodger, E. M., Property requirements for liquid rocket propellants, Coll. Aero., Cranfield, Note 97, 32 pp., Nov. 1959.

An analysis is made of the properties necessary for liquid rocket propellants to give effective performance with acceptable handling. Typical propellants are examined against this requirement background, and their relative suitability assessed.

From author's summary

5439. Blackman, V. H., A comparison of two approaches to an electric propulsion system, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958); Pergamon Press, 1959, 1111–1123.

Elementary review of plasma propulsion, discussing plasma jet and magnetically driven plasma guns of various types. Some experimental results obtained with argon and helium plasma jets are presented, but accompanying discussion seems based on over-optimistic estimates of specific impulse. Plasma guns are only qualitatively discussed and compared with plasma jet.

G. H. Markstein, USA

5440. Mirels, H., and Rosenbaum, B. M., Analysis of one-dimensional ion rocket with grid neutralization, NASA TN D-266, 43 pp., Mar. 1960.

Study is based on one specific configuration consisting of an ion-emitting grid, an accelerating grid, and a decelerating-neutralizing grid. Random thermal motion of the ions and electrons is neglected. Various forms of possible potential distributions along the beam axis are discussed in some detail. The potential in the ion-electron beam downstream of the neutralizing grid is shown to have a periodic structure of small wavelength [see also NASA TN-D-261; following review]. A similar wave structure may exist also upstream of this grid if it is located relatively far downstream of the accelerating grid. Over-all thrust and the focus that act on the individual grids are derived from momentum integrals. Specific impulse and electric-power requirements are discussed briefly. The spacing between the accelerating and the neutralizing grid does not affect thrust or specific impulse; when it is relatively large, electrons move upstream from the neutralizing grid and tend to reduce excessive spreading and current reversal of the ion beam.

G. Rudinger, USA

5441. Kaufman, H. R., One-dimensional analysis of ion rockets, NASA TN D-261, 35 pp., Mar. 1960.

Space-charge effects in ion and electron accelerators are analyzed to determine major design problems and performance limitations without going into details of hardware design. Uniform particle velocities are assumed at first, and the analysis is then refined by considering Maxwellian velocity distributions. Advantages of designs based on the accelerate-decelerate principle are demonstrated. To avoid an unreasonably large cross-sectional area of the neutralizing electron beam, electron velocities must be considerably larger than those of ions. Excessive electron velocities cause part of the beam to go upstream, toward the ion accelerator; the total electron current must then be sufficiently large that the downstream-moving portion is able to neutralize the ion beam. As a result of the difference between ion and electron velocities, the potential field downstream of the beam exit exhibits periodic fluctuations. Their wavelength, given by the ion velocity divided by the plasma frequency, generally is small compared to the dimensions of the physical system.

G. Rudinger, USA

Magneto-fluid-dynamics

(See also Rev. 5439)

Book—5442. Bershader, D., edited by, The magnetodynamics of conducting fluids, Stanford, Calif., Stanford University Press, 1959, viii + 145 pp. $4.50.

This small book comprises seven papers which formed the main subject matter of the third symposium on magnetohydrodynamics sponsored in November 1958 by the Lockheed Missiles and Space Division. Despite the title, a connected account of the subject is not presented. None of the papers gives a treatment elementary enough to constitute an introduction to the subject.

In the opening contribution, A. Busemann considers problems of flow existence and stability of field-free, infinitely conducting plasmas contained in, or bounded by, magnetic field, a situation he calls "magnetic bedding." With his characteristic insight author combines intuitive and mathematical analysis in a study of magnetic Laval nozzles and current-carrying single and double wires. For the double wire a simple modification of the classical two-dimensional steady flow about a cylinder containing a source-sink doublet is shown to hold. The magnetic dipole (double wire) rotated $\pi/2$ from the flow doublet position will produce a similar magnetohydrodynamic flow providing the hydrodynamic pressure falls to zero at the point of maximum velocity.

The magnetically bedded two-dimensional potential flow is analyzed according to the variational formulation due to Bateman (e.g. Vol. 3, Princeton Series on "High Speed Aerodynamics and Jet Propulsion," pp. 38–40) and is shown to lead to an extremum wherein the dynamic and magnetic contributions are at maximum and minimum respectively. Thus the result for the total problem of subsonic mhd flow is inconclusive. Finally, in order to study ways of improving the contour between the varied magnetic field and dynamical flow areas so that magnetic and dynamic pressures become equal, the single wire case is studied in the unsteady situation of perturbations of the circular contour separating the magnetic and flow fields. The small-disturbance theory first treated analytically by Friedrichs is needed as background to assure the presence of two differing propagation velocities. Here the mathematical treatment becomes somewhat murky and the conclusion is unclear. The form of the sinusoidal boundary disturbance which reduces the difference between magnetic and dynamic pressure variations to zero is such that vanishing of pressure jumps at the critical point where maximum velocity occurs cannot be guaranteed. While the nonexistence of the flow is not decisively proven, need for caution in accepting its existence is certainly indicated. These remarks do not reflect the exhilarating effect on the reviewer of Busemann's penetrating discussion.

The second paper, by J. D. Cole, considers waves set up by a conducting piston impulsively set in motion with constant velocity into a conducting medium bearing an initial magnetic field. Conservation equations for the problem are set up in an interesting way with help of the Maxwell stress tensor, yet turn out in the end to be identical with those of Friedrichs. For the fluid of infinite conductivity the possibility of three wave speeds is shown, in agreement with Friedrichs' unpublished findings. A restrictive condition is pointed out which later leads to the study of switch-on shock waves. For finite conductivities a linearized version is given whose solution can be obtained via the Laplace transform. Under asymptotic approximations the motion is seen to consist of a wave diffusing outward with time from the trajectory determined for the ideal perfectly conducting case. Author then returns to consider the switch-on shock for both ideal and resistive fluid employing the previously used techniques. Mathematical difficulties prevent the author from showing conclusively that an expansion follows the weak switch-on shock in a medium with finite conductivity, although he asserts that a crude approximative integration yields this result. Paper is an interesting and informative variant from Friedrichs' treatment of the perfectly conducting case and yields solutions for the dissipative case which provides specific examples of the general results predicted by Whitham [*Comm. Pure Appl. Math.* **12,** p. 113, 1959; AMR **13**(1960), Rev. 965].

H. Grad opens his lengthy discussion with a statement of the Lundquist equations in both the complete and linearized form. He then proceeds to review the results of the small-disturbance theory pertaining to characteristic and normal speed loci. Author's eclectic approach is somewhat different from that of previous papers and reports published by the NYU group, but his conclusions are essentially the same. After brief consideration of the nonlinearized one-dimensional problem in characteristic form, author passes to the resolution into separate modes of the linearized, general problem in three dimensions. He indicates as special solutions both (1) two types of transverse Alfvèn waves which propagate unattenuated in one dimension, and (2) compressive waves in three-dimensions traveling with the slow or fast sound speed. With the aid of certain auxiliary variables a resolution into transverse and compressive modes of an arbitrary solution of the linearized problem may be accomplished, but only at the expense of domain of dependence difficulties of a strange sort. These seem to arise from the fact that, in process of inverting to find the original variables in terms of the auxiliary variables, elliptic instead of hyperbolic equations occur; so that while the auxiliary variables propagate with usual wave properties, the transverse and compressive parts in the original variables are harmonic functions specified by initial data over the entire domain and thus not necessarily zero (although their sum must vanish) in regions yet to be affected by waves in the auxiliary variables.

When the Alfvèn speed is much larger than the sound speed, a further separation into slow or fast modes is possible. A local separation may be made such that the longitudinal magnetic field component is carried isotropically at the Alfvèn speed, while the longitudinal component of velocity is carried one-dimensionally at the much smaller gas speed. A compressive density jump is carried by both waves. The remaining transverse components go with the fast wave. No transverse residue is left by the slow wave. When Alfvèn speed is much smaller than sound speed the situation is much more complicated; separation is possible only in a restricted sense in terms of auxiliary variables which involve solutions of Poisson's equation when inverted. Author closes by discussing the physical conditions under which these various special solutions may be observed. In particular he suggests that signals in the geomagnetic field, e.g. "whistlers," may be interpreted as more complicated special cases of the unattenuated, one-dimensional modes given by the theory. Generally speaking, author's style is terse and proofs are sketched or merely indicated. Much is left to the reader.

Mitchner's paper is mainly concerned with the magnetohydrodynamic flows analagous to inviscid, isentropic (a) non-steady one-dimensional flows and (b) steady two-dimensional, irrotational flows of conventional fluid mechanics. Some of his results either duplicate or extend the general theorems concerning these same analogies given by Grad and Blank in their report NYO–6486(1958). Mitchner develops the one-dimensional flow theory appropriate to the shock tube in considerable detail. These calculations and resulting design curves should be of great interest to those experimenters who are generating magnetically driven shock waves. He makes comparisons with some of the available experimental results from magnetic shock tubes and finds order of magnitude agreement. The experiments differ in so many details from the theoretical model assumed that precise comparisons cannot be made.

The contribution by Fishman, Lothrop, Patrick and Petschek is noteworthy because it is the only paper offering original experimental and theoretical results. Authors consider problem of a widely spaced solenoid transverse to a supersonic flow of a moderately conducting gas. By a perturbation treatment of the mhd equations they obtain expansions for all the flow variables in terms of powers of the magnetic Reynolds number and the magnetic interaction parameter which measures the ratio of actual magnetic force to dynamic pressure in the gas. An interesting departure from the equations applicable to a moderately conducting fluid occurs because of the introduction of extra terms into a generalized and probably controversial Ohm's law to account for the Hall effect and ion slip effect in the partially ionized gas [cf. H. S. Green, *Physics of Fluids* **2,** p. 341, 1959].

The experiment consists in passing the flow produced by an hydrogen-argon, chemically driven shock tube over transverse, current-carrying helices. For small currents, i.e. small magnetic interaction parameter, only a weak interaction characterized by variable luminosity along the coil cross section is seen. For strong currents the coil behaves more like a solid cylinder and shows a detached bow shock followed by intense luminosity. Asymmetry of the shock is attributed to Hall effect and estimates yield a lift-drag ratio of about one. Fairly good quantitative agreement is obtained between experimental and calculated luminosity values.

Resler and McCune consider the linearized magneto-aerodynamic equations where finite conductivity and transport effects due to a uniform flow are included. They discuss under suitable boundary conditions the two problems of steady flow along a wavy wall and

flow over a thin airfoil. In the first of these they discern the mechanisms of propagation via Alfvén waves and diffusion of the disturbance normal to the propagation direction. They conclude that fluid effectiveness as a conductor depends not only on conductivity through the magnetic Reynolds number but also on the configuration geometry. In the second they find combined hyperbolic and elliptic behavior in the partial differential equations. Presumably this is the same phenomenon noted by Grad in his companion paper. Plots are given for the cases of flow and magnetic fields either crossed or aligned, indicating regions where purely hyperbolic, elliptic or combined hyperbolic-elliptic behavior will occur. Solutions analagous to the conventional Ackeret theory are indicated and an analog to the Prandtl-Glauert rule is formulated.

In the final contribution Carrier and Greenspan give what amounts to an extended abstract of their work on mhd flow past a flat plate. This paper has already appeared elsewhere [*J. Fluid Mech.* **6**, p. 77, 1959] and presumably will be reviewed separately.

The volume under review has the same format as its predecessors in the series. It is attractively printed and bound. Reviewer has noticed only a few misprints. Reviewer believes book will be of interest and value to workers in the field but that question may be raised whether binding symposium papers of this sort into one volume is as valuable as letting the separate contributions find their way into print through the usual channels. The normal process of refereeing could conceivably have resulted in improvements in clarity and in pruning out some of the repetitious material.

Reviewer protests the unfortunate situation in magnetohydrodynamics illustrated in this volume. Three of the papers refer to the inaccessible Los Alamos report by Friedrichs or its sequel NYO-6486 by Friedrichs and Kranzer published by New York University (available on request). No easily obtainable source of Friedrichs' analytic study exists in the open literature; yet ready understanding of the contents of the present volume is almost impossible without it. Reviewer feels that the scientific community would benefit substantially from publication of a complete and connected account of Friedrichs' work. F. D. Bennett, USA

5443. Korobeinikov, V. P., Similarity-type one-dimensional motions of a conducting gas in a magnetic field, *Soviet Phys.-Doklady*, **3**, 4, 739-742, Apr. 1959. (Translation of *Dokladï Akad. Nauk SSSR (N.S.)* **121**, 4, 613-616, July-Aug. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

One-dimensional unsteady motion of an infinitely conducting gas is studied. A magnetic field is assumed to be perpendicular to the direction of motion of the gas. The gas may be moving as a plane wave or an expanding cylindrical wave. A dimensional analysis of the equations of motion fixes the form required for similarity solutions. The results are applied to three problems: (1) The motion of a gas with given initial conditions (Cauchy problem); (2) the motion of a compressible gas pushed by a piston started impulsively; (3) a strong detonation. L. H. Schindel, USA

5444. Wu, C. -S., A class of exact solutions of the magnetohydrodynamic Navier-Stokes equations, AFOSR TN 58-895 (Princeton Univ., Dept. of Aero. Engng. Rep. 436; ASTIA AD 204 134), 51 pp., Sept. 1958.

A class of similarity solutions of the magnetohydrodynamics Navier-Stokes equations has been found in this paper so that the original differential system may reduce to two ordinary differential equations. The equation which governs the velocity field appears to be of first order but with a nonlinear interaction term of the magnetic field. On the other hand, the magnetic induction equation is of second order. Solutions similar to that obtained by Landau and Squire for nonmagnetic case are found by using a perturbation expansion of small α (α is the ratio of kinematic viscosity and magnetic viscosity).

Throughout the analysis, the fluid is assumed to be incompressible, viscous and electrically conducting. The physical properties are also postulated to be constant.

From author's summary by D. C. Leigh, USA

5445. Weymann, H. D., Electron diffusion ahead of shock waves in argon, AFOSR TN 60-334 (Inst. Fluid Dynam. Appl. Math., Univ. Maryland TN BN-197), 16 pp., Mar. 1960.

Experiments with electrostatic and magnetic probes were performed to investigate the electron diffusion ahead of shock waves of $M_s - 8$ to 12 in argon. Negative electrostatic signals of several volts were obtained with pronounced fronts propagating with velocities of up to several times the shock velocity. The current produced by the diffusing electrons was determined from a measurement of the aximuthal magnetic field and found to be of the order of 10^{-5} amp for $M_s = 12$. Assuming that the electron flow velocity is approximately equal to the velocity of the electrostatic front the measured current corresponds to an electron density of n_e 10^7 cm^{-3} at about 1 m ahead of the shock front.

From author's summary

5446. Barach, J. P., Experimental investigations of the interaction between a shock and a magnetic field, AFOSR TN 60-439 (Inst. Fluid Dynam. Appl. Math., Univ. Maryland TN BN-203), 29 pp., Mar. 1960.

A magnetic interaction has been observed with flows of Mach number about 15 in krypton and inhomogeneous magnetic field of about 50,000 gauss. The loss of momentum flux in the gas flow is proportional to the magnetic impulse taken up to a point where there seems to be a sudden adjustment of flow velocity. The position of this point is determined by the parameter $\sigma \nu B^2/P$. The higher this parameter, the earlier the interaction and the less its total effect. Moderately low values of the parameter produce the largest effects. From author's summary

5447. Regirer, S. A., Nonstationary problem of magnetohydrodynamics for a half-space, *Soviet Phys.-Doklady* **4**, 4, 782-785, Feb. 1960. (Translation of *Dokladï Akad. Nauk SSSR (N.S.)* **127**, 5, 983-986, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author considers flow of viscous, electrically conducting fluid in semi-infinite space in presence of a transverse magnetic field. Proof of four theorems gives nature of solutions analogous to those in classical hydrodynamics obtained, for example, by Rayleigh. Reduction to classical solution is shown when magnetic field vanishes. W. C. Griffith, USA

5448. Carrier, G. F., and Greenspan, H. P., The time-dependent magnetohydrodynamic flow past a flat plate, *J. Fluid Mech.* **7**, 1, 22-32, Jan. 1960.

The paper consists of two parts. In the first part authors consider a semi-infinite flat plate which is moved impulsively in its own plane into an electrically conducting viscous fluid. The ambient magnetic field has the same direction as the motion of the plate. The fluid is assumed to be incompressible. The fundamental system of equations consists of equations of Navier-Stokes and those of Maxwell. The introduction of the vector potentials of velocity and magnetic field simplify the system of equations to two partial differential equations which are linearized by means of using the appropriately chosen averages in place of the nonlinear coefficients. The resultant equations are solved by means of the Fourier-Laplace transforms and the Wiener-Hopf process. The finite value of the skin friction coefficient function shows that one can distinguish three regions: the first in which the skin friction is precisely that of the steady-state problem; the second one, further downstream, is that which an infinite plate would experience. In between there occurs a smooth transition. The prediction that

the only steady flow is one in which the fluid and plate undergo a rigid body motion is fully substantiated.

Part II of the paper treats the classical Rayleigh motion in a magnetic field: an infinitely extended thin plate is immersed in an unbounded viscous fluid and, at time zero, is suddenly given a constant velocity in its own plane. The uniform ambient magnetic field is perpendicular to the plane of the plate. For convenience authors use polar coordinates and dimensionless quantities. A solution is obtained by means of Laplace transforms with the boundary conditions expressed in matrix form. The resultant expression is inverted term by term, giving the consecutive terms in the series expansion for the horizontal velocity component. The first two terms in this expansion represent waves whose propagation speeds are the Alfvèn speeds. In particular, the second term represents a reflected wave. The third term is half as big as the second one, and, in fact, all subsequent terms decrease in size as a geometric series.

A useful lesson drawn from the paper is the reminder that the replacement of conceptually acceptable three-dimensional problems by more tractable two-dimensional ones must be carefully justified.

M. Z. v.Krzywoblocki, USA

5449. Lyubimov, G. A., Shock waves with discontinuous gas conductivity situated in an electromagnetic field, *Soviet Phys.-Doklady* **4,** 3, 510–513, Dec. 1959 (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **126,** 2, 291–294, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.).

A shock-wave system is considered assuming an infinite conductivity behind, and zero-conductivity in front, of the shock. It is shown that it is impossible to have small disturbances with an infinite jump in the conductivity. From the author's general discussion of this particular problem it is concluded that, for instance, in the case of a steady flow of a gas with a high supersonic velocity about a plane contour in the presence of an electromagnetic field, the solution in the region behind the shock must be of the form $\mathbf{v} = k\mathbf{H}$.

D. Ter Haar, England

5450. Patrick, R. M., High-speed shock waves in a magnetic annular shock tube, *Physics of Fluids* **2,** 6, 589–598, Nov./Dec. 1959.

Paper describes experiments in magnetic annular shock tube [see Kemp, N. H., and Petschek, H. E., "Theory of the flow in the magnetic annular shock tube," *Physics of Fluids*, **2,** 6, 599–607, Nov./Dec. 1959; AMR **13**(1960), Rev. 5452, this issue].

Experiments were carried out with two magnetic field configurations ahead of the shock front, the first with a magnetic field ahead of the shock front in the direction of motion of the shock. In the second configuration the magnetic field ahead of the shock had its principal component in the plane of the shock front and a small component in the direction of the shock motion. The continuum radiation emitted by the shock-heated plasma was measured with photomultipliers. Use of probes to measure the change in the local magnetic field in the shock front was investigated. With the second configuration, shock velocities in excess of 4×10^7 cm/sec were measured in hydrogen. For these high-speed shock waves, shock thicknesses, obtained from measured rise times of the emitted visible radiation, are thinner than the mean free path in the shock-heated plasma, an observation which agrees with a theoretical prediction.

A. H. Shapiro, USA

5451. Rossow, V. J., Boundary-layer stability diagrams for electrically conducting fluids in the presence of a magnetic field, NASA TR R-37, 16 pp., 1959.

See AMR **12**(1959), Rev. 2092.

5452. Kemp, N. H., and Petschek, H. E., Theory of the flow in the magnetic annular shock tube, *Physics of Fluids* **2,** 6, 599–607, Nov./Dec. 1959.

Symmetry conditions prevailing in an annular tube allow relatively simple and accurate calculations of events which occur when a shock wave is driven longitudinally down the tube by means of a magnetic field. High-temperature plasmas are readily produced. The various wave configurations (simple waves; fast and slow shocks) are deduced from the laws of fluid dynamics and Maxwell's equations. Numerical calculations of the significant flow properties were made for a complete range of the initial field strength and orientation, and are presented graphically.

A. H. Shapiro, USA

5453. Scott, F. R., and Wenzel, R. F., Moving magnetic field behind a strong deuterium shock, *Physics of Fluids* **2,** 6, 609–613, Nov./Dec. 1959.

By introducing a spiral in the return conductor of a conical discharge tube with a hollow electrode, a magnetic multipole has been observed propagating down a cylinder extending out from the hollow electrode. This magnetic field appears to have an extremely complicated internal structure when observed with small magnetic probes; when observed by an external loop, the net axial leakage flux shows a structure consistent with the characteristics of a shock-produced deuterium plasma.

From authors' summary by A. H. Shapiro, USA

5454. Kulikovskii, A. G., Concerning Riemann waves in magnetohydrodynamics, *Soviet Phys.-Doklady* **3,** 4, 743–746, Apr. 1959. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **121,** 6, 987–990, July–Aug. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

The Riemann or "simple" wave solutions are determined for a perfect gas of infinite conductivity. The appropriate solutions are found to be the differential equations of magnetohydrodynamics using essentially the same method as employed by Friedrichs and Kranzer [Notes on magneto-hydrodynamics **VIII**: Nonlinear Wave Motion, Institute of Mathematical Sciences, N.Y.U., NYO-6486, July 31, 1958].

The results also are in similar form to those of Friedrichs giving, in general, three possible propagation velocities. The behavior of the waves is studied qualitatively, indicating which compression waves will become shocks and which can propagate as rarefaction waves.

L. H. Schindel, USA

5455. McCune, J. E., On the motion of thin airfoils in fluids of finite electrical conductivity, *J. Fluid Mech.* **7,** 3, 449–468, Mar. 1960.

Author considers a two-dimensional, small-perturbation theory for the steady motion of thin lifting airfoils in an incompressible conducting fluid, with the applied uniform magnetic field perpendicular to the undisturbed uniform flow field. The conductivity of the fluid is assumed to be such that the magnetic Reynolds number, R_m, of the flow is large but finite. The governing equations of magneto-aerodynamics are linearized and reduced (by taking curls and cross-differentiating) to two linear partial differential equations. Next, author shows that the resultant equations can be solved exactly for an elementary sinusoidal mode, yielding a solution valid for any value of R_m. The final expressions refer to the two velocity and magnetic field vector components in the upper half plane. As a first application of this solution, author constructs the expression for the pressure on the surface of the wavy wall and for the drag per wavelength. The results obtained for sinusoidal modes are used through Fourier synthesis to provide the basis to study the flow field associated with a lifting airfoil of small camber moving in a fluid of large but finite conductivity. The first approximations to the velocity and magnetic field vector components are identical.

The next item treated is the boundary conditions appropriate to thin airfoils in the usual form. This leads to the formulation of the boundary-value problem for the potential flow, satisfying the Kutta

condition (finite velocity at the trailing edge). The entire procedure is applied to thin airfoils in two cases: direct problem, i.e. boundary-value problem when the analytical expression for the airfoil curve is given. In this case the Glauert series is used and the resultant lift coefficient contains a factor depending upon magnitude of the magnetic field strength. But the simple results obtained in this approach cannot be applied since the profile shapes that correspond to this family of solutions are quite unusual. The indirect problem (wherein the pressure is specified and the profile shape is required) is solved for an elliptic loading only, with the plots of airfoil camber lines. The calculation of the current penetration and the discussion of the error for the large R_m approximations close the paper. M. Z. v.Krzywoblocki, USA

5456. Hord, R. A., and Pennington, J. B., Temperature and composition of a plasma obtained by seeding a cyanogen-oxygen flame with cesium, NASA TN D-380, 18 pp., May 1960.

The temperature and composition of a cyanogen-oxygen flame seeded with cesium are calculated approximately by assuming that the combustion is adiabatic and that the product mixture is in thermodynamic equilibrium. For initial mole fractions of cesium up to 0.1 and flame pressures from 0.01 to 1 atmosphere, electron concentrations up to 4.4×10^{16} per cubic centimeter and plasma temperatures in the range of 4000° to 5000°K are obtained.

From authors' summary

5457. Golitsyn, G. S., Some problems of the dynamics and heating of a conducting medium in a magnetic field, *Soviet Phys.-JETP* **10,** 4, 756-760, Apr. 1960. (Translation of *Zh. Eksp. Teor. Fiz., Akad. Nauk SSSR* **37,** 1062-1067, Oct. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.).

One-dimensional motion of a perfectly conducting medium under the action of a magnetic field prescribed at the boundary is considered. Confinement of the plasma by a high-frequency magnetic field is investigated. Some aspects of the problem of heating the plasma by magnetoacoustic waves are discussed.

From author's summary

5458. Shajenko, P., Effect of magnetic field on transfer characteristics of particles in an electric arc, *Welding J.* **39,** 2, 83s-88s, Feb. 1960.

Transfer characteristics of metal particles under arc-blow conditions can be controlled by balancing the magnetic forces acting on the arc or offsetting their effects.

From author's summary

Aeroelasticity

(See also Revs. 5289, 5329)

5459. Chu, W.-H., and Abramson, H. N., An alternative formulation of the problem of flutter in real fluids, Southwest Research Institute, Dept. Engng. Mech., 17 pp., Aug. 1958.

Authors analyze the incompressible potential flow about a harmonically oscillating thin airfoil. Essential difference from classical solution lies in replacing the Kutta-Joukowski condition at trailing edge by a generalized condition, which ultimately results in two empirical undetermined (in general, complex) parameters, to be determined by experimental means. No attempt is made to use available experimental data to determine above parameters for particular airfoil, although results of a computation with an arbitrary 10° phase lag in the circulation function $C(k)$ is shown to result in improved correlation of calculated and experimental phase angle difference between lift and harmonic airfoil oscillations.

Reviewer finds significance of work difficult to evaluate critically barring the availability of appropriate experimental data from which empirical parameters may be evaluated, which would permit application to flutter calculations. Such calculations would be of interest, particularly for flutter of airfoils and possibly hydrofoils at very low mass ratios ($\mu \lesssim 2$-3) where classical theory is particularly inadequate. More work along these and similar lines is clearly desirable in view of the increasingly higher speeds being attained by hydrofoil craft and underwater craft using hydrodynamic control surfaces. W. G. Brady, USA

5460. Abramson, H. N., and Chu, W.-H., A note on panel flutter as a problem in hydroelasticity, Southwest Research Institute, Dept. Engng. Mech., Oct. 1959, 9 pp.

The present state of knowledge concerning the aeronautical problem of subsonic panel flutter is discussed briefly, followed by some speculations relative to the application and importance of this information to hydroelastic problems.

From authors' summary by H. Bergh, Holland

5461. Kharlamov, A. A., Simulation by modelling of the aerodynamic reactions of an oscillating wing in a plane flow (in Russian), *Nauchn. Dokladf Vyssh. Shkoly. Fiz.-Matem. Nauk* no. 1, 149-154, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6148.

This is an investigation by means of electromechanical modelling of the deflection-torsion flutter of a semirigid wing in a plane transonic flow of air. In the electromechanical model the section of the wing is represented by a stiff beam elastically fastened on two springs which enables changes to be made over a wide range in the mass and elastic characteristics of the wing. The corresponding aerodynamic reactions on the wing section were reproduced by means of two vertical forces to which could be added the aggregate of all the aerodynamic forces affecting the oscillating wing. The magnitude of the vertical forces corresponding to the given motion of the wing was ensured with the aid of an electronic model of the aerodynamic forces. By selecting a suitable electric arrangement of suitable parameters, modelling of the aerodynamic reaction on a section of the wing was achieved in conformity with the accepted aerodynamical theory. The principal electrical designs for the electromechanical modelling of the deflection-torsion flutter are explained, the bases being the so-called hypothesis of the stationary state and the nonstationary theory of the wing. The investigation on these lines showed satisfactory agreement between experiment and theoretical calculations and confirmed the possibility of electronic modelling of aerodynamic forces when examining the oscillations in parts of an airplane.

V. A. Altukhov

Courtesy Referativnyi Zhurnal, USSR

5462. McWithey, R. R., and Vosteen, L. F., Effects of transient heating on the vibration frequencies of a prototype of the X-15 wing, NASA TN D-362, 21 pp., May 1960.

A prototype of the X-15 wing has been tested under simulated aerodynamic heating conditions to determine any changes in the effective stiffness of the wing. Experimental results indicate no large changes in effective stiffness as a result of the heating conditions. A theoretical calculation of the change in torsional stiffness indicates the same change in stiffness as that obtained experimentally. From authors' summary

5463. Campbell, L. G., Jr., Walton, R. P., Stimpson, L. D., Jr., Miles, J. W., Thomson, W. T., Fung, Y. C., and Wener, N. L., Aeroelasticity in stability and control, WADC TR 55-173, 494 pp., Mar. 1957.

This is a comprehensive treatment of those aspects of aeroelasticity which are most important in problems of aircraft stability and control. The aim is not to give a complete theoretical treatment of the subject but to present sufficient technical material to enable a practicing engineer to understand aeroelastic phenomena and to perform design calculations. Methods are given for incor-

porating aeroelastic effects in the equations of motion, as well as techniques for obtaining their solutions. Matrix methods are emphasised throughout this work.

Basic concepts and background material are presented in Chapters 1–4. Both modal and collocation methods of analysis are given, and their relative merits are detailed. The present knowledge of unsteady flow theory is dealt with very fully in Chapter 5, which also contains a summary of known results and a comprehensive bibliography. The simplified method, using modified derivatives, is given, together with simplified estimates of static aeroelastic effects on both longitudinal and lateral stability and control.

Chapters 6 and 7 contain applications of the methods to the analysis of the stability of airplanes and helicopters. The use of digital and analog computers in solving aeroelastic problems is discussed in Chapter 8, and flight test methods in Chapter 9.

Throughout the book, the treatment is kept close to the practical. Only the currently used techniques are outlined. Although it is tough reading for the beginner, this book provides the first useful practical survey of the field. In particular, the very extensive list of references will be invaluable to research workers.

A. W. Babister, Scotland

5464. Morozov, D. K., Influence of the flow on a floating ground cable (in Russian), *Nauchn. Trudî Odessk. In-ta Inzh. Morsk. Flota* no. 19, 101–111, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6304.

The conditions are examined in which the power of a flow reacts on a floating ground cable. Models of the pontoons of the installation to scales of 1 : 10 and 1 : 6.67 were tested in an experimental tank. Each of the models was pulled along at different velocities and at various angles between the geometrical axis of the model and the direction of the motion. This gave a relation between coefficient of velocity and the given angle.

V. V. Smyslov

Courtesy Referativnyi Zhurnal, USSR

Aeronautics

(See also Revs. 5138, 5278, 5287, 5288, 5289, 5334, 5376, 5455, 5478, 5480)

5465. Pinsker, W. J. G., Preliminary note on the effect of inertia cross-coupling on aircraft response in rolling manoeuvres, Aero. Res. Counc. Lond., Curr. Pap. 435, 70 pp., 1959.

Several advanced aircraft designs have suffered coupled lateral and longitudinal motion and subsequent loss of control during rolling maneuvers. W. H. Phillips has identified the four major trends which are responsible. His work is based on a reduced system of Euler equations referred to the principle inertia axes and linearized for constant roll rate. For the complete response during a practical roll with varying roll rate the nonlinear equations must be examined.

This paper is an initial report on a general study of these five equations using GEPUS, a general purpose simulator at RAE. Its objective is to simulate a systematic series of aileron inputs and to determine principally the peak responses in incidence and sideslip. Characteristics of a typical supersonic fighter with linear aerodynamic derivatives varied for incidence are used.

Results indicate that large amplitudes of incidence and sideslip near roll termination, as well as low critical autorotational rates, can quite reasonably occur. Attempts at autostabilization show excessive control movements. Gravity effects are found negligible.

Presentation is well organized and admirably developed.

D. E. Ordway, USA

5466. Campbell, G. S., and Weil, J., The interpretation of nonlinear pitching moments in relation to the pitch-up problem, NASA TN D–193, 32 pp., Dec. 1959.

Report presents method and examples for predicting maneuvering quality of hypothetical fighter airplane from static wind-tunnel data and inertial characteristics. Measured drag, lift, and pitching-moment coefficients are substituted as nonlinear functions of angle of attack; contributions of stabilizer and elevator deflections as well as rates of pitch and angle of attack are linearized. For part of investigations speed was assumed constant and flight path angle small.

Solution of equations of motion obtained from digital computers showed that the pull-up maneuvers produced by various rates of stabilizer deflections differ in pace but reach almost the same peaks of angle of attack. Pilot has little chance of avoiding a large over-shoot if he starts counteractions one second after pitch-up becomes apparent.

Effect of shape of pitching moment curves is illustrated by solutions for 10 different moment curves. For small dynamic response factors (load in fuselage) corrective control is effective; for large dynamic response factors (load in wing) corrective control is too slow. A change of pitch damping makes little difference. Automatic stabilization using angle of attack as input can eliminate pitch-up completely.

G. W. Braun, USA

5467. Scher, S. H., Anglin, E. L., and Lawrence, G. F., Analytical investigation of effect of spin entry technique on spin and recovery characteristics for a 60° delta-wing airplane, NASA TN D–156, 52 pp., Dec. 1959.

Complete six degrees-of-freedom spin equations of fighter aircraft were solved on digital computers in order to find why aircraft model spun in vertical wind tunnel with about twice the rate (converted to full scale) and 10 degrees higher angle of attack than full-scale aircraft. Reynolds number difference did not sufficiently explain discrepancy. However, initial conditions used in starting spin in tunnel and initial conditions for starting spin in flight led to two different types of spin equilibrium similar to those observed.

G. W. Braun, USA

5468. Whitehead, D. J., The low speed approach and catapult launch problems in high performance naval aircraft, *J. Roy. Aero. Soc.* **64,** 592, 183–198, Apr. 1960.

5469. Jackson, R. P., and Southcote, M. F., Potential of the air-cushion vehicle, *Aero/Space Engng.* **19,** 3, 40–47, Mar. 1960.

Estimates of the gross power requirements are summarized and extended to include estimates of the payload-range capability. These data are then utilized to illustrate the "working rate" capability of "off-the-road" air-cushion vehicles compared with more conventional transportation media.

From authors' summary

5470. Campbell, J. P., Research on VTOL and STOL aircraft in the United States, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958), Pergamon Press, 1959, 845–892.

5471. Keith-Lucas, D., Safety and reliability aspects of VTOL, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958), Pergamon Press, 1959, 893–913.

5472. Eggers, G., and Ernst, G., Mechanics of VTOL flight (in French), Advances in Aeronautical Sciences, Vol. 2, (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958), Pergamon Press, 1959, 914–926.

Astronautics

(See also Revs. 4999, 5024, 5116, 5278, 5298, 5392, 5393, 5397, 5487, 5523)

5473. Sedov, L. I., Orbits of cosmic rockets toward the moon, *ARS J.* **30,** 1, 14–21, Jan. 1960.

A brief discussion of some techniques used by the Russians in planning the flights of their three lunar space vehicles. The paper includes thorough summaries of flight parameters and characteristics of the actual trajectories. Approximation methods are used for rough analyses, whereby a "sphere of influence" of radius 66,000 km is established, on either side of whose surface the motion is appropriately Keplerian. For more detailed calculations, a sophisticated program incorporates perturbation effects into the machine solution of the equations of motion. Results are plotted as contours in a phase plane which permits the determination of orbital perigee and apogee, closest lunar approach distance and orientation of the orbital plane with respect to the moon.

Although analytical details are lacking, as is any description of the formulas employed for precision orbit calculations, the paper does present a good deal of numerical orbit data characterizing the flights, several interesting trajectory diagrams, and some commentary on the practical considerations involved in executing the three missions. S. E. Ross, USA

5474. Yegorov, V. A., The capture problem in the three-body restricted orbital problem, NASA TT F-9, 16 pp., Apr. 1960.

Proof is presented of a theorem connected with the question of capture in the restricted orbital three-body problem. It is shown that in the case where one of the attractive masses is sufficiently small with respect to the other, a point of zero mass starting infinitely far away cannot remain forever in the sphere of attraction of the smaller mass, that is, become its satellite.

From author's summary

5475. Moe, Mildred M., An approximation to the re-entry trajectory, *ARS J.* **30,** 1, 50–53, Jan. 1960.

The Allen-Eggers approximation [NACA TN 4047] is improved to include the effects of gravity as well as air resistance. The equations of motion are transformed into integral form in terms of the trajectory angle. The re-entry angle is used for a trial solution and the integrals evaluated assuming a constant drag coefficient and an exponential atmospheric density.

The method gives a good approximation if the re-entry angle is greater than 5 degrees and if the trajectory angle does not change greatly. Even if the latter condition is violated the qualitative nature of the trajectory is correctly given; the method could be applied piecewise in this case. Calculations for a wide range of weight-drag ratios and initial conditions are compared with exact solutions. In comparison with the Allen-Eggers results the reported method gives a better value for the vehicle speed, approximates the trajectory curvature, and provides a reasonable estimate of the re-entry range. S. Ostrach, USA

5476. Friedlander, A. L., and Harry, D. P., III, Requirements of trajectory corrective impulses during the approach phase of an interplanetary mission, NASA TN D-255, 53 pp., Jan. 1960.

Authors consider a particle approaching a fixed Newtonian force center. At some instant the position and velocity vectors correspond to a hyperbolic orbit with perigee P_1. What impulse should be given the particle to put it in an orbit with perigee P_2? Of the possible answers the authors find the one which minimizes the velocity change. Numerical values of the magnitude and direction of the minimum impulse vector are given for a wide variety of initial conditions. The effects of small errors in the thrust direction and the possibility of using impulses in directions other than the optimum are worked out in detail. It appears, as might be expected, that a considerable economy in corrective thrust is achieved by correction at a distance from the focus large compared with P_2.

L. E. Goodman, USA

5477. Graham, E. W., and Beane, B. J., Optimum trajectories with atmospheric resistance, Douglas Aircr. Co. Rep. SM-23745, 44 pp., Nov. 1959.

Problems involving the transfer of a rocket vehicle from one point to another with minimum fuel expenditure are considered. The transfer time and the terminal velocity vectors are specified.

The first problem studied is one in which atmospheric resistance is the only external force acting on the vehicle. In the second problem both atmospheric resistance and centrally directed gravitational forces are included. (The case in which centrally directed gravitational forces are the only forces appearing has been considered previously.)

In all cases there is employed a translating but nonrotating coordinate system whose origin follows a coasting trajectory between the terminal points. The linearized perturbation force field in this coordinate system is used. Two different methods are employed. One is a method of bounds which yields information which is general, but not complete or precise. In the second method the equations of motion in the moving coordinate system are used, and the results are more precise but not so simple and general in their application.

The methods are by no means intended to replace the methods of variational calculus, but should supplement them and perhaps provide a somewhat different viewpoint for examining such problems. Some attempt has been made also to obtain a physical understanding of the factors which determine the desirability of using intermediate impulses in some cases while terminal impulses alone are optimum in other cases. From authors' summary

5478. Grant, F. C., Dynamic analysis of a simple reentry maneuver for a lifting satellite, NASA TN D-47, 35 pp., Sept. 1959.

The maneuver is designed to put the re-entry vehicle on a glide trajectory after a single skip by a properly chosen zero-lift coasting period.

The effects of wing loading were generally small. The higher lift-drag-ratio maneuvers were possible only at the higher re-entry angles. The minimum re-entry angle for a successful maneuver at a high lift-drag ratio was sharply reduced by the lower energy level. The precision of the maneuver was highly sensitive to the time of the start of coast. Coasting distances of less than 1,000 nautical miles were only possible for lift-drag-ratio values under about 2.

Maximum normal accelerations had a roughly parabolic variation with re-entry angle. The highest value calculated was 4.7g at a lift-drag ratio of 5 for a wing loading of 100 pounds per square foot and a re-entry angle of 6°.

From author's summary by A. Petroff, USA

5479. Vinti, J. P., Theory of the spin of a conducting satellite in non-equatorial orbits, BRL Rep. 1031, 73 pp., Oct. 1957.

Eddy currents induced in shell of conducting satellite traveling through earth's magnetic field decrease angular velocity of rotation to considerable extent. Magnitude of this damping torque can be important if, as in case of Tiros meteorological satellite, a particular spin is required.

In an earlier report author treated general problem of spin of a conducting satellite and showed that torque arising from interaction with magnetic field consisted of a decay component tending to diminish the angular velocity and a component tending to turn the axis of rotation. For the case of a spherical satellite in constant magnetic field (approximated by circular equatorial orbit), spin component parallel to magnetic vector remains constant while component perpendicular to magnetic vector decays exponentially with time.

In present report author develops an approximate theory for spin of conducting satellite in non-equatorial orbit. Differential equations for the three components of spin are derived and simplified for digital computation by prior removal of all but low-frequency periodic components (the only components author considers to have significant amplitude). For a polar orbit it is shown that if the component of spin for a spherical satellite perpendicular to the equatorial plane does not vanish initially, spin approaches perpendicularity to equatorial plane. For inclined orbit with spin not initially perpendicular to equatorial plane, spin eventually becomes parallel to equatorial plane. Graphs are presented showing spin decay and rotation of spin axis for several circular orbits of inclination 41.268°. W. W. Berning, USA

5480. Loh, W. H. T., Hypervelocity glider at large angles of inclination, *ARS J.* **30,** 2, 201–202 (Tech. Notes), Feb. 1960.

Author considers glider at large, variable angles of inclination and at constant lift/drag ratio, moving at orbital re-entry speeds. Using a differential equation from his previous work [*ARS J.* **29,** 522–523, July 1959], which dealt with large, constant angles of inclination, and assuming high re-entry speeds, author obtains approximate expressions for flight velocity, flight altitude, distance along flight path, flight range, flight deceleration and maximum deceleration, time rate and maximum time rate of average and of local stagnation region heat input, total aerodynamic heat input, and flight time of glider. If gravity term is neglected at high speed re-entry, except in terminal phase of flight, the equations obtained are all simplified. D. Abir, Israel

5481. Blagonravov, A. A., Some problems of providing for scientific research on rockets, *ARS J.* **30,** 1, 22–27, Jan. 1960.

Author described "several particular solutions that made possible research with the aid of rockets." These are solutions to the following problems of probe instrumentation: (1) isolation of the various apparati from disturbances caused by the booster, as well as from each other, (2) safe parachute recovery of sounding rocket payloads, (3) attitude control of space vehicles, in one instance by a gyro-wheel accelerator, in another case by vernier jet control, (4) heat-control system for maintaining an acceptable temperature range within Lunik III, (5) design and installation of solar batteries on board Lunik III, (6) construction and instrumentation of animal-carrying capsules in high-altitude tests, and in Sputnik II.

Several diagrams illustrate the mechanisms utilized for the various jobs. The accompanying discussions are informative, although they can hardly be considered detailed.

S. E. Ross, USA

5482. Camac, M., Use of energy storage in low thrust spaceflight, *ARS J.* **30,** 1, 54–63, Jan. 1960.

Flight plans for spacecraft propelled by power-limited low-thrust systems are analyzed under the condition that energy is stored over a portion of an orbit revolution. In this way greater freedom in thrust programming is possible.

Particular consideration is given to the storage of electric energy in batteries to provide a short thrust impulse at a point along the orbit. Recycling of this process is assumed. The performance with and without energy storage is compared for two types of missions in the Earth's gravitational field: (1) round trips from small to larger circular orbits, and (2) rendezvous maneuvers between orbits at low altitudes.

It is shown in case 1 that even with the extra weight of the storage batteries, some flight plans are possible which reduce both the flight time and propellant requirements. For case 2 many flight plans require that thrust be applied at only limited portions of the orbit. With energy storage, all the available energy can be utilized, thereby substantially decreasing flight time and the guidance problem. S. Ostrach, USA

5483. Johsman, W. E., Mass considerations in ring supported solar sails, *ARS J.* **30,** 3, 287–288 (Tech. Notes), Mar. 1960.

For a solar sail a ring satisfying stability and strength condition must be chosen. From equations of motion for a sail normal to sun's rays the critical load and maximum acceleration may be found, and lower bound on ring mass obtained. High modulus, low density ring material will reduce the mass requirements; in an example beryllium is chosen. It is shown that the mass of the ring can be made a very small fraction of solar sail if a hollow pressurized torus is used instead of solid ring. Adding spokes is less effective. Development of highly reflective plastic for sail is desirable. P. Bielkowicz, USA

5484. London, H. S., Some exact solutions of the equations of motion of a solar sail with constant sail setting, *ARS J.* **30,** 2, 198–200 (Tech. Notes), Feb. 1960.

Problems of solar sail navigation yield as solutions logarithmic spiral and conic section trajectories depending on sail setting. In a paper by Tsu log spiral solutions were obtained from approximate equations where a term $\dot{r}$ in the radial acceleration is neglected. In present paper solutions are deduced without making such approximation and results apply to larger range of values for spiral angle and acceleration. Tangential thrust in an inverse square gravity field may produce a logarithmic spiral if the thrust-to-mass ratio of the vehicle is varied as $1/r^2$. This is exactly the case of radiation pressure. Substitution of log spiral equation into the equations of motion for solar sail yields relation between the sail setting, spiral angle ψ and acceleration α due to radiation pressure. Curves are plotted for several values of α. Values of α greater than 0.342 cm per sec^2 yield only radial flight path as solution, for α less than 0.342 cm per sec^2 two solutions are possible. Flight time can be calculated for given spiral angle. For radial sail setting (sail normal to sun's rays) the value of sun's gravity constant is reduced by a constant in the equations, whose solutions are conic sections. Transfer orbits can be computed. The cotangential transfer to Mars would take 286 days as compared to 259 days on the ballistic Hohmann transfer and about 247 days on optimum log spiral, but in general neither a logarithmic spiral nor conic section solution is optimum.

P. Bielkowicz, USA

Ballistics, Explosions

(See also Revs. 5305, 5420, 5473)

5485. Struble, R. A., A study of the interior ballistic equations (in English), *Arch. Rational Mech. Anal.* **3,** 5, 397–416, Sept. 1959.

Author is concerned only with the mathematical implications of the assumed interior ballistic equations, so that "the degree to which these equations or their solutions represent the physical situation are not considered," thus correcting the trend by which "useful aspects of the mathematics appear to be lost in the zeal for correlation with experimental data." Unrealistically, he is "interested (only) in those solutions corresponding to a zero shot start pressure." He accepts for the form function, $(1 - f)(1 - \theta f)$, which gives degressive burning for $\theta > 0$, progressive for $\theta < 0$. Curious results obtained include (1) in the degressive case, the pressure "must ultimately return to zero" (before the web is completely burnt through), and "a physically significant trajectory is limited to (stages prior to all-burnt)." The paper claims "characteristics of the pressure curves are obtained for the entire spectra of the ballistic parameter (sic. he gives three such parameters), burning coefficient and geometric parameter." No graphs or tables are given. A. A. Bennett, USA

5486. Sen, H. K., and Guess, A. W., Radiation effects in shock wave structure, *Phys. Rev.* **108,** 3, 560–564, Nov. 1957.

Equations for shock-wave structure are derived with radiation pressure, energy density and energy flux included as well as hydrodynamic effects such as viscosity and heat conduction. The Rankine-Hugoniot relations are also obtained. Computations were performed for a perfect gas in local thermal equilibrium, in which the radiation flux is given by a diffusion approximation and the radiation pressure and energy density are neglected. The results indicate that the effect of radiation flux can be taken as a diminution in gas Prandtl number. The shock width, both with and without radiation, decreases as Mach number increases ($1.5 < M < 4$), but the ratio of shock thickness with radiation to that without radiation increases as Mach number increases, indicating that radiation becomes more important at higher Mach numbers. Reviewer believes results applicable only to nuclear blasts. The theory might possibly be extended to low-density hypersonic shocks although here the assumption of thermodynamic equilibrium would not be valid. Mary F. Romig, USA

5487. Loh, W. H. T., Spinning ballistic missiles, *J. Aero/Space Sci.* **26,** 12, 844–846 (Readers' Forum), Dec. 1959.

Introduction points out differences in approach and point of view of aerodynamists and ballisticians. Use of linearized theories for large angles of yaw at times results in considerable inaccuracy. This prompted author's investigation of nonlinear equations. For available aerodynamic coefficients at large angles of yaw solutions are obtainable on digital computer. One right-hand coordinate system is fixed to earth and another set with reference to c.g. of missile. Author also introduces symbols defining missile's instantaneous position. Matrices are used for transformation equations. Aerodynamic forces and moments are resolved into a system of components with reference to missile's moving coordinates and are tabulated and identified. Author represents motion of axially symmetrical missile after cessation of thrust, using 22 independent equations containing 22 unknowns, which may be solved.
V. A. Valey, USA

5488. Soloukhin, R. I., and Topchiyan, M. E., Investigation of the tail of spinning detonation, *Soviet Phys.-Doklady* **4,** 4, 773–775, Feb. 1960. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **127,** 4, 772–773, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N.Y.)

5489. Philipchuk, V., Fabrication by explosives, *Mech. Engng.* **82,** 5, 48–50, May 1960.

Acoustics

(See also Revs. 5303, 5307, 5308)

5490. Fay, R. D., Spherical waves of finite amplitude, *J. Acoust. Soc. Amer.* **31,** 10, 1377–1379, Oct. 1959.

A method is presented for the analysis of spherical waves of finite amplitude. An example of the application of the method is given for the case of repeated shock waves. This method of analysis has the same limitations as the corresponding method applied to finite plane waves. The relative simplicity of the method, however, may be useful in practical cases.
R. C. Binder, USA

5491. Eby, R. K., Williams, A. O., Jr., Ryan, R. P., and Tamarkin, P., Study of acoustic propagation in a two-layered model, *J. Acoust. Soc. Amer.* **32,** 1, 88–99, Jan. 1960.

The study of the propagation of sound in shallow water received its first important stimulus from World War II field observations. Theoretical studies undertaken to explain these observations culminated in the solution of the idealized two-layered problem by C. L. Pekeris in 1948. Since then considerable field data have been obtained; sometimes in good agreement with theory, and, on other occasions in agreement only if questionable assumptions concerning the environment were made. These results, combined with other considerations, (difficulty of numerical computation, simplicity of laboratory as contrasted to field experiments, etc.) stimulated controlled model experiments. While these experiments upheld the Pekeris solution, it was frequently found that deviations from the idealized boundary conditions had a large effect on the character of the propagated field. This suggested the need to determine the perturbing effects of surface and bottom irregularities.

To the reviewer's knowledge, the present paper is the first published comprehensive attempt to study the bottom perturbations and includes consideration of sloping bottoms, shear wave excitation, and bottom roughness. Theoretical considerations and model experimental data are presented. Sonar engineers concerned with layered propagation would be well advised to carefully study its contents. M. S. Weinstein, USA

5492. Ballin, J. L. S., and Beyer, R. T., Scattering of sound by sound, *J. Acoust. Soc. Amer.* **32,** 3, 339–341, Mar. 1960.

An attempt was made to determine the presence of scattering resulting from the nonlinear interaction of two finite-amplitude sources, operating in water. Experiments were performed with two beams crossed at right angles and also in the nonperpendicular case. A detector crystal, tuned to the summation frequency (13.4 Mc) of the two sources (7.4 Mc and 6.0 Mc), and pivoted about a point above the interaction region, was used to investigate the scattered field. The results indicated no scattered sound above the noise level of the detection system. The lack of scattered sound is in agreement with the theoretical considerations of Westerbelt, but is contrary to the predictions of Ingard and Pridmore-Brown. From authors' summary

5493. Nesterov, V. S., Viscous-inertial dispersion and attenuation of sound in a highly concentrated suspension, *Soviet Phys.-Acoustics* **5,** 3, 344–351, Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 337–344, July/Sept. 1959 by Amer. Inst. Phys., New York, N.Y.)

The problem of sound propagation in a highly-concentrated suspension is solved by means of a schematic model consisting of small cylinders and a small quantity of viscous liquid penetrating the solid particles. Equations are obtained for the complex density, velocity, and attenuation of sound as a function of frequency and the geometric and mechanical parameters of the suspension. The application of the theory to specific cases is pointed out.
From author's summary

5494. Cheng, S.-I., On the aerodynamic noise of a jet, AFOSR TN 59-1308 (General Applied Science Laboratories, Inc. TR 148), 56 pp., Apr. 1959.

In Lighthill's theory jet noise is generated by fluctuating Reynolds stresses $\rho v_i v_j$ (quadrupoles) within the jet. Author attempts to allow for convective, refractive, and other effects by replacement of these by "cells of quadrupoles ... distributed along the outer edge of the jet to serve as effective images of radiating quadrupoles in the interior ...." To this end he traces mathematically the propagation of linearized waves through jet velocity field idealized as parallel shear layer of infinite downstream extent. The waves are ultimately specialized as quasi-plane sound waves and their refraction is determined. (Reflection is overlooked and total reflection replaced by a fallacious "absorption" and "re-emission" through the layer of zero phase velocity, cf. Fig. 3).

The plane acoustic waves appear to be identified in one development with Fourier components of the turbulent fluctuations (which reviewer considers inadmissible): they are used to deduce

approximate changes in $\rho v_i v_j$ between interior and boundary of jet to provide strength of "image" quadrupoles there. In a fashion not clear to reviewer, directional radiation from "images" is related to plane wave refraction throughout frequency spectrum.

More or less qualitative arguments based on above are used to predict dependence of polar peak noise level on jet speed. It is further concluded that downstream emission should vary as U^8 without convective increases of exponent and that emission normal to jet should vary as U^6.

Reviewer's general comments: By application of Kirchoff's theorem all of the generative, convective and refractive processes for the sound within a jet may be replaced by a certain distribution of sources and dipoles on a bounding surface in quiescent air enclosing the jet; the sound field outside this surface will be the same. Author's "image" quadrupoles attempt to usurp the role of these sources and dipoles. The procedures do not constitute a proper application of Kirchoff's theorem and reviewer has grave doubts as to their justification on any alternative basis.

H. S. Ribner, Canada

5495. Mackenzie, K. V., Formulas for the computation of sound speed in sea water, *J. Acoust. Soc. Amer.* **32,** 1, 100–104, Jan. 1960.

This paper summarizes and brings up to date the many measurements and computations of the velocity of sound in the sea which have been systematically performed since 1924. Formulas for computations, including correction terms for salinity, temperature, depth, and latitude, are presented along with critical comment concerning their use and accuracy. This paper is of interest to the sonar specialist concerned with the effect of very small changes in sound velocity.

M. S. Weinstein, USA

5496. Garrison, G. R., Murphy, S. R., and Potter, D. S., Measurements of the backscattering of underwater sound from the sea surface, *J. Acoust. Soc. Amer.* **32,** 1, 104–111, Jan. 1960.

Extensive experimental surface reverberation data obtained at a frequency of 60 kilocycles per second are presented and correlated with meteorological and wave-height data obtained simultaneously. The most important results are: (1) Correlation of reverberation level with surface wind velocity, the reverberation level rising with wind velocity and saturating at velocities in excess of 14 knots. (2) Large rain drops cause near-maximum reverberation. (3)Wind- and rain-induced reverberation is caused by the production of small surface ripples. (4) In other respects previously reported results are confirmed (effect of sound intensity at the surface, and area insonified, angular dependence, mechanisms of reverberation).

This paper is a must for underwater sound engineers concerned with devices which either utilize or are adversely effected by surface reverberation.

M. S. Weinstein, USA

5497. Sagar, F. H., Acoustic intensity fluctuations and temperature microstructure in the sea, *J. Acoust. Soc. Amer.* **32,** 1, 112–121, Jan. 1960.

This paper is concerned with the origin of the thermal patches (microthermal structure) in the sea which result in fluctuations of transmitted sound intensity. A summary and analysis of previously published (unclassified) work is given. Experimental fluctuation data are provided for several ocean areas, particularly for New Zealand waters. New experiments which should be performed are described. This paper is of interest to engineers concerned with advanced sonar systems.

M. S. Weinstein, USA

5498. Heckl, M., and Seifert, K., Investigation of the influence of natural frequencies of measurement chambers on the results of transmission loss measurements (in German), *Acustica* **8,** 4, 212–220, 1958.

A one-dimensional model serves for the theoretical and experimental investigation of the transmission loss (TL) due to a sound insulator placed between two "rooms" in the shape of coaxial tubes of equal diameter. The theoretical value of the TL for this model and the experimental value agree fairly well, vary periodically with the frequency, and show pronounced minima at the resonant frequencies of the second "room." If, in particular, the two "rooms" are of equal length, then the measured TL is, for all frequencies investigated, smaller than the "true" TL (given by 10 log (power incident/power transmitted)).

A theory for three-dimensional rooms is sketched, and it is shown that the measured TL is not independent of whether the source is located in the small or the large room. Estimates are given for this effect as a function of room size and frequency.

R. Heller, USA

5499. Vinogradov, K. N., and Ul'yanov, G. K., Measurement of the velocity and attenuation of ultrasonic surface waves in hard materials, *Soviet-Phys.-Acoustics* **5,** 3, 296–299, Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 290–293, July/Sept. 1959 by Amer. Inst. Phys., New York, N. Y.)

The velocity and attenuation of ultrasonic surface waves in certain metals, alloys, and glass are measured. Exact measurements of the velocity are made by the method of standing waves on a special apparatus by means of a contactless magnetoacoustic transducer. The attenuation is measured by the pulse method. For the excitation and reception of the ultrasonic signals wedge transducers with a variable angle are applied.

From authors' summary

5500. Lina, L. J., and Maglieri, D. J., Ground measurements of airplane shock-wave noise at Mach numbers to 2.0 and at altitudes to 60,000 feet, NASA TN D-235, 25 pp., Mar. 1960.

Measurements of sonic-boom intensities were made for flights at altitudes to 60,000 feet and Mach numbers to 2.0. The measurements were made on the ground near the flight tracks. Effects of altitude, flight-path angle, Mach number, and atmospheric refraction at the cutoff Mach number were investigated. The effects of airplane size and weight were determined by a comparison of measurements made from one flight of a supersonic bomber with data for the supersonic fighter which was used for most of the tests.

From authors' summary

Micromeritics

(See also Rev. 5049)

Book—5501. Symposium on particle size measurement (Sixty-first Annual Meeting, American Society for Testing Materials, Boston, Mass., June 26–27, 1958), Philadelphia, Pa., American Society for Testing Materials, 1959, v + 310 pp. $6.25.

A collection of 17 papers, dealing with various aspects, methods, and instruments of measurement of solid particles in suspension, as to size, and size-distribution. All are written by experts and the papers represent the up-to-date state of science and technology pertinent to the subject. Of special value are the numerous discussions which clear up doubtful points and stimulate further thought on the individual subjects. Titles of papers follow, with brief indications of their contents: (1) "Mechanics of fine sieving" discusses influence of several variables, such as mesh size, sieve loading, sieve motion, and others, on the result of test sieving. (2) "Application of electroformed precision micromesh sieves to the determination of particle-size distribution" describes the properties of electroformed nickel sieves with precise square openings ranging from 15 to 105 micron. (3) "Measurement of physical properties of cracking catalysts" discusses terminology, methods of measurement of density, pore volume, and particle

size by various methods. (4) "Methods of particle size analysis" discusses mainly two microscopic methods: (a) the count method for determining the average particle size, and (b) the direct measurement of the individual particles. (5) "Recent developments in the hydrometer method as applied to soils" discusses changes by ASTM in the method of grain-size analysis of soils, adopted in 1954, in particular the modification in the hydrometer to be used. (6) "Sedimentation procedures for determining particle size distribution" discusses sedimentation theory, and the advantages and disadvantages of several techniques. (7) "Centrifuge sedimentation size analysis of samples of airborne dusts collected in membrane filters" describes capillary centrifuge tubes whereby size analysis of fractional milligram quantities of dusts can be carried out. (8) "A liquid sedimentation method for particle size distributions" describes a refinement of the method treated in (7). (9) "Determination of particle size distribution by examining gravitational and centrifugal sedimentation according to the pipette method and with divers" describes a method using a tall sedimentation column from which samples can be taken at various stages of the sedimentation process, or in which divers, i.e., small floating bodies having accurately determined specific gravities, can be placed to float at a level at which the liquid suspension has the same specific gravity. (10) "A photoelectric sedimentation method for particle size determination in the subsieve range" whereby the change of light absorption is measured as the sedimentation progresses. (11) "Light-scattering instrumentation for particle size distribution measurements" comprising a right-angle illuminating system in conjunction with a moving aerosol stream and a photometer to receive the reflected light. (12) "Turbidimetric particle size distribution theory: Application to refractory metal and oxide powders" surveys a number of theories for turbidimetry and sedimentation, analyzes their error sources, especially as regards their applicability to powders. (13) "Electronic size analysis of subsieve particles by flowing through a small liquid resistor" describes instrumentation for measuring the electrical resistance of an electrolyte containing particles in suspension as they pass through a small aperture. (14) "The determination of particle size by adsorption methods" describes methods and apparatus for determining surface area of particles by measuring their absorption of gases and liquids. (15) "A study of the Blaine fineness tester and a determination of surface area from air permeability data" discusses the variables entering into the use of this instrument and their effect on accuracy of results. (16) "A discussion of the ASTM recommended practice for reporting particle size characteristics of pigments (D1366)" gives exact definitions for concepts as: particle size parameter, coarseness parameter, and dispersion parameter for characterizing fineness. (17) "The Stanford Research Institute Particle Bank" discusses the use and usefulness of a collection of particulate samples of which the characteristics have been exactly determined. Finally, the ASTM standards for particle size measurement are listed.

K. J. DeJuhasz, USA

Book—5502. Mintz, D. M., and Schubert, S. A., The hydraulics of granular substances (in Russian), Moscow, Izd-vo M-va Kommun. Kh-va RSFSR, 1955, 112 pp.; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9013.

The investigation of the resistance to the flow of a fluid through suspended layers of a granular substance is conducted on the basis of an analysis of a great number of experimental data published in the literature, and obtained by the present authors. Applying the dimensional theory, authors obtain the usual expressions for the coefficient of resistance (drag coefficient), and the Reynolds number R. For the case of filtrational motion (infiltration), they suggest as the characteristic length, the hydraulic radius of the cross-section of the medium, and as the characteristic velocity, the so-called virtual rate of filtration. The hydraulic radius is defined as the quantity reciprocal to the total surface of all grains in a unit volume. Then

$$R = \frac{\rho_1 v d_{eq}}{6\mu\alpha(1-m)} \qquad [1]$$

$$\eta = \frac{P_m{}^3 d}{L\rho_1 v^2 6\alpha(1-m)} \qquad [2]$$

where ρ, μ are the density and viscosity of the fluid; d_{eq} the equivalent diameter of the particles; m the porosity; α a coefficient representing the form of the particles; P/L pressure gradient per unit length of the porous medium; v the ordinary velocity (rate) of filtration. For a free fall of the particles the parameters must be expressed in terms of the velocity of relative motion, u, and the equivalent particle size, d_{eq}.

The most characteristic feature of a suspension of granular particles is the fact that over a particular range of velocities, from the commencement of removal of the particles, the pressure gradient remains constant, and equal to the weight of the suspended layer. As the velocities increase, the quantity of particles in unit volume decreases, and the porosity of the layer increases. Consequently, experiments for investigating the law of resistance to the motion of the liquid through the layers in suspension become exceedingly simple, and are reduced to measuring the variations in the thickness of the layer with varying velocity. Applying Eqs. [1] and [2], authors arrive at a simple relationship between η and R, at least for the finer fractions ($d < 3$ mm) of the sand. This relationship can be expressed by a binomial formula

$$\eta = \frac{C}{R} + \eta_{eq} \qquad [3]$$

in which C is a quantity depending on the particle diameter; η_{eq} limiting value of the drag coefficient for R tending to infinity; which, in the author's opinion, is proportional to the drag of free-falling particles in a fluid.

Applying the definitions of [1] and [2], Mintz has evaluated a large number of experimental data on the filtration of different liquids and gases through dense (close-packed) layers of spherical bodies, and has obtained an equation for the linear resistance

$$\eta = (5.1/R) \qquad [4]$$

which he recommends for general use. It should be noted that Eq. [4] as well as the parameters [1] and [2], for filtration through dense layers, can be of only limited application. The conception of the hydraulic radius introduced by the authors is only convenient to use in the case of suspended layers. For the investigation of filtration through porous layers, on the other hand, instead of being difficult to determine porosity m and the incompletely definable particle size, varying within wide limits both in magnitude and in shape, it is far more convenient to use the expression of the parameters by the coefficient of permeability. Assuming, for dense minerals and for suspended layers, binomial expressions of externally identical form, and applying Eq. [4], authors are able to calculate the value of the coefficient C in Eq. [3]. Equations and charts are given, enabling calculation of the constrained precipitation of solid particles in a fluid, determination of the critical rate of suspension, calculation of the expansion of the granular layer in the ascending flow of the fluid, etc.

In conclusion, a description is given of the authors' own experiments on the investigation of the resistance of suspended layers. Detailed tables of the experimental data are included.

E. M. Minskii

Courtesy Referativnyi Zhurnal, USSR

5503. Rajagopal, E. S., Statistical theory of particle size distributions in emulsions and suspensions (in English), *Kolloid Z.* **162**, 2, 85–92, Feb. 1959.

Paper presents a derivation of the "log-normal distribution" for particle sizes in a mathematically defined (Markoffian) size-reduction process. Author claims that the model represents turbulent emulsification, but no analytical connection to hydrodynamics is offered. S. Corrsin, USA

5504. Romankov, P. G., Lepilin, V. N., and Nemet, E. S., Some problems of the aerodynamics of a suspended layer in the conditions of a narrow pipe (in Russian), *Trudí Leningrad Tekhnol. Inta Im. Lensovieta* no. 39, 28–33, 1957; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 8996.

The process is investigated of the formation of a layer of a suspension in glass tubes with a diameter of 32, 49 and 52 mm respectively. The suspended layer consisted of particles of irregular shape and low mechanical strength. The diameter of the particles varied from 0.5 to 3.5 mm, initial depth of the layer from 50 to 500 mm, and the specific gravities from 0.482 to 1.08 g/cm³. Air was blown through the layer. It is demonstrated that, previous to the formation of a pseudo-liquefied layer, the resistance increases as the flow velocity. In the range between the velocity at the commencement of suspension and the velocity at which all particles are in a state of suspension, the resistance decreases somewhat; after which, after passing the velocity of total suspension, the resistance becomes constant and equal to the weight of the layer. Analysis of the experimental data leads to an equation determining the loss of head in this velocity range

$$\Delta p = 1.02 \frac{G}{S}$$

wherein Δp is loss of head in the layer, G weight of the layer, S cross-sectional area of the pipe. The divergence from unity of the value of the numerical coefficient is explained as due to functional losses. When the velocity rises to a certain critical value the granular material begins to be carried away; and the flow resistance falls abruptly. The particular characteristics of the motion of the suspended substance are described in detail; a chaotic displacement of the particles in the layer is observed, which confirms the observations of other workers to the effect that pulsations and channelling then appear in the suspended layer.

E. M. Minskii

Courtesy Referativnyi Zhurnal, USSR

5505. Rafales-Lamarca, E. E., The hydrodynamics of the processes taking place in gravity concentration and their modelling (in Russian), Sb. Trudí Labor. Gidravl. Mashin Akad. Nauk USSR no. 6, 142–158, 1956; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9000.

Analyzing the processes of gravity concentration, author obtains an equation for the equilibrium of the forces acting on an isolated body contained in an unsteady fluid flow. The apparent weight of the body in the fluid G' is determined by the Archimedean law; the force of frictional resistance, R_c, by Newton's equation (a square-law relationship to the velocity); the supplementary lift force ΔP arising due to acceleration and equalling $a\rho_{fl}v$ (where a is the acceleration of the fluid, ρ_{fl} the density of the fluid, and v the volume of the body) follows from the single-value equation of Euler; the supplementary force required to overcome the inertia force R_{pr} is determined by the equation:

$$R_{pr} = K\rho_{fl} V d(v - w)/dt,$$

where K is coefficient of the reduced mass, v and w, the respective velocities of the fluid and the body. Thus the particle is influenced by a unit force I, equal to

$$I = -G' \pm R_c + \Delta P + R_{pr}.$$

For the modelling of the processes of gravity concentration in ponderous suspensions it is proposed to observe the identity of two nondimensional parameters γ_{fl}/γ_T and v^2/dg, where γ_{fl} and γ_T are the volume weights of the water and the particle, d the diameter of the particle, and g the acceleration of gravity. In order to model the process of precipitation, a term is introduced in the equation of equilibrium of the forces acting on the individual particle, representing the resistance due to collision of the particles, which depends on the coefficient of disintegration of the grain structure, θ. As a similarity criterion for the process of precipitation, it is proposed to use the expression $ln^2/\theta\bar{\gamma}_T g$, where l is the amplitude of pulsation, $\bar{\gamma}_T = \gamma_T/\gamma_{fl}$, n the number of oscillations per minute. The problem is investigated of the formation of "pseudosuspensions," i.e., a loose mass of separate small grains, formed in the ascendant semi-period of the pulsation cycle, and their influence on the process of concentration. Analytical relationships and the corresponding curves are presented for the dimensions of the concentrated material, the amplitude of pulsation and the number of pulsations per minute, on the one hand; and the similarity criterion of the precipitation, on the other hand. In the author's opinion, his curves should be checked against operational and experimental results; but even in their present form they are useful for orientation in assessing the work of gravity concentrators (classifying jigs) used for the concentration of coal. U. Ts. Andres

Courtesy Referativnyi Zhurnal, USSR

5506. Mirzoyeva, L. M., The determination of the solid-phase concentration in a diphase system moving upwards in a vertical pipe (in Azerb.), *AzerbSSR Elmler Akad. Kherberlerli* no. 9, 11–19, 1957; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 8993.

In view of the "slipping" effect particularly apparent in a vertical pipe, the actual concentration of the solid phase in the motion of a binary (solid + liquid phase) system will always be greater than the calculated value. The amount of slip, σ, is determined by the ratio of the difference between the absolute velocities of the carrying and suspended phases, and the velocity of the carrying phase. It is demonstrated by the simplest transformations that the gravimetric concentration of the solid particles in an air flow moving in a vertical pipe, K'_G, in the presence of slipping, is associated with the corresponding concentration in the absence of slipping, K_G, by the relationship

$$K'_G = K_G/(1 - \sigma).$$

An analytical formula is given for determining the quantity σ in relation to the flow velocity, rate of motion of the particles, and the calculated gravimetric concentration of the solid substance; some illustrative examples are also analyzed.

U. Ts. Andres

Courtesy Referativnyi Zhurnal, USSR

Porous Media

(See also Revs. 5122, 5123, 5124)

Book—5507. Pirson, S. J., Oil reservoir engineering, 2nd ed., New York, McGraw-Hill Book Co., Inc., 1958, x + 735 pp. $14.

The well-known book of Prof. Pirson on oil reservoir engineering has been recently issued in a second edition, quite different from the first one; in fact the seven chapters of the first edition have become 14, and the 440 pages expanded to 735.

The general plan of the book is explained in the Introduction. Oil Reservoir Engineering may be defined as the art of forecasting the future production of oil or gas reservoirs. Therefore it is necessary to know the external driving fluid energy under hydrostatic head, the internal driving energy from gases in solution at reservoir pressure, the potential energy due to the action of body forces, the surface energy (as a result of capillary forces).

According to this plan the first chapter deals with reservoir rocks and structures. Here oil reservoirs are classified on the

basis of origin and geological configuration, mineral composition and texture of the reservoir rocks, and here also are indicated the relations between geology and reservoir performance.

Chapter two studies the physical properties of reservoir rock, i.e. considers porosity, fluid saturation and permeability. Relations between rock properties and reservoir behavior are also investigated.

Chapter 3 deals with petrophysics, i.e. studies the relationships that exist between physical and textural rock properties.

Chapters 4 and 5 deal with electric and radiation logging of wells and with quantitative interpretation of well-logs; they are in large part entirely new in respect to the first edition. This is a subject that author has studied in many papers, and the results are very interesting.

Chapter 6 studies reservoir-fluid properties, i.e. those physical and chemical characteristics of the fluid which are useful for determining the behavior of reservoirs.

Chapters 7 and 8 consider the reservoir forces and energies (of the kind explained in the introduction) and the mechanics of porous media, and Chapter 9 deals with volumetric and empirical oil reserve estimate.

The four next chapters concern the most important questions of oil production: they deal with oil production by depletion drive, oil production by frontal displacement, oil production by water drive, and oil production by segregation drive. Calculations are given for every system of production.

The last chapter (the 14th) gives a unified theory of reservoir engineering. In the reviewer's opinion this is an important work, one of the first to appear, in the field of reservoir engineering.

G. Supino, Italy

5508. Bear, J., Scales of viscous analogy models for ground water studies, *Proc. Amer. Soc. Civ. Engrs.* **86,** HY 2 (*J. Hydr. Div.*), 11–23, Feb. 1960.

Hele-Shaw analogy may be used to study fluid flow through porous media, representing flow by means of a model formed in the space between two parallel plates. Equation of phreatic line may be written considering no flow across it, and flow governed by Darcy's law. When nonisotropic aquifer is considered, different values of viscosity apply to coordinate directions. Since Hele-Shaw model is isotropic, distorted length scales result from comparison of prototype and model phreatic lines. From this comparison, times scales may also be computed. Discharge scale is obtained from Darcy's law and volume scale from continuity equation. For nonhomogeneous aquifers, model with variable interspace is suggested. Next, model for aquifer with specific storage coefficient is considered. Viscosities and specific weights are analyzed for model of two fluids in an aquifer. Capillarity and its effects are also considered in analogy.

A. Balloffet, USA

5509. Maidanik, G., The flow of fluids through capillaries, powder beds and porous media, *Trans. Faraday Soc.* **56,** 445, 118–127, Jan. 1960.

Fluid flow by density gradient through such media as capillaries, powder beds or porous media is examined in the paper. The total specific conductance of the sample is $D_T = D + D_S + D_R$, where D is inherent to the mechanism of diffusion (i.e. when distances traversed by molecules are large in comparison with the average mean free path); D_S is the term associated with the slip, and D_R is identified with Poiseuille's formula of flow. A satisfactory theoretical derivation of D_S being lacking, author develops a semi-empirical theory, basing the slip on the interaction of the molecules of the fluid with the surfaces of the sample. The final formula giving values of D_R may be simplified because of the constancy of some terms. Values of D_T in a reduced form are plotted on graphs with the ratio between a typical linear dimension of the sample (in function of the fraction f of molecules undergoing scattering on the surfaces of the sample, the others being specularly reflected, after Maxwell's suggestion on statistical basis), and the mean free path corresponding with the mean pressure. The linear dimension is next computed by author for the special cases of uniform capillaries and powder beds. Results seem to agree with experimental results by other authors.

A. Ghetti, Italy

5510. Galli, L., Approximate calculation of seepage under hydrological structures (in Hungarian), *Viz. Kozl.* **3,** 355–392, 1959.

This paper seeks to evaluate, by the simplest analytical means, the ground-water seepage in laminated soils, either in vertical or in horizontal direction, caused by the weight of buildings or hydrological structures (river-dams). The computations are based on Darcy's law, considering the quantity of seepage water, the lost pressure heads : ' the resistance to flow of pore water. Only one-dimensional ground-water flow is treated, using as a typical stratification in the river valleys in Hungary three typical, homogeneous soil layers: a cohesive upper cover, a transition, and a permeable lower layer. Simple examples of such cases are described, including several numerical examples, and cases when artificial pressure-relieving drains (water wells) are present, either as a single well or as a row of wells. While the author admits that the flow may be three-dimensional in space and unsteady, he reviews only one-dimensional, steady cases of flow.

A. Nadai, USA

5511. Mkhitaryan, A. M., Filtration from a channel on a sloping water-revetment (in Russian), *Sb. Nauchn. Trudi Kuibyshevsk. Industr. In-ta* no. 7, 139–142, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6536.

A solution is given with the aid of a hodograph of velocities for the problem of a plane steady unpressurized filtration (following d'Arcy's principle) in a homogeneous stratum with a sloping sole on the assumption that the boundary of the stratum is inclined in relation to the horizon. Author proposes to make use of a case of filtration investigated by him when calculating the filtration from a channel. The results of the solution are not presented in a form suitable for application. Errors and misprints noted were: (1) in formula [1] instead of $\zeta - 1$ should be $1 - \zeta$; (2) on page 131 nine lines from the bottom in the expression for v_y the minus sign is omitted; (3) in the expression for the magnitude of M the magnitudes i and $e^{i\pi\beta}$ should be omitted and the magnitude $\cos \pi\alpha$ should be substituted by the magnitude $\sin \pi\alpha$, and, in conjunction with these corrections, formula [6] must be corrected as also the expressions for the magnitude $dz/d\zeta$ and z; (4) in formula [8] the magnitude H should be taken out; (5) on page 142 six lines from the bottom instead of ctg β, ctg $\pi\beta$ should be inserted.

S. N. Numerov

Courtesy Referativnyi Zhurnal, USSR

5512. Muskhelishvili, V. L., Experimental investigation of the aerodynamic resistance of a fragmented layer (in Russian), *Trudi Gruz. Politekhn. In-ta* no. 2 (59), 154–161, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6550.

Special apparatus was used to investigate the aerodynamic resistance of a layer of broken-up limestone. Using coordinates $\omega - h$ curves were drawn for various heights for the layer of the material, where ω was the mean velocity of the motion of the air, h was the loss of pressure. The curves are describable by the equation $h = a\omega^n$, where $1 < n < 2$, which indicates a transitional regime for the flow of air through the layer. The coefficient of resistance of the broken-up layer is approximately described by the equation

$$f' = \frac{3.58}{R^{0.2}}$$

and does not depend on the dimensions of the pieces.

U. Ts. Andres

Courtesy Referativnyi Zhurnal, USSR

5513. Levi, I. I., and Kulesh, N. F., Motion of flows into water reservoirs when the flow is saturated with fine silt, and the features of calculations for the accumulations of silt in such reservoirs (Thesis of the report) (in Russian), *Trudí Labor. Ozeroved. Akad. Nauk SSSR* **7,** 87–90, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6366.

When a river flow enters a reservoir with its waters containing a heavy concentration of fine earths a suspension is formed in the lower region of the reservoir, the longitudinal forces of the surplus weight of which is sufficient to cause an autonomous displacement or motion along the bottom in the form of a "heavy flow." Data are furnished for the first stage of the experimental study of this type of flow, which included the velocities of the flow, the general resistance and the lower limit of the concentration. These data are utilized for the derivation of an equation for the irregular motion of a flow containing a high concentration of fine sediment.

V. N. Goncharov

Courtesy Referativnyi Zhurnal, USSR

5514. Gheorghita, St. I., Flows in harmonically nonhomogeneous porous media (in English), *Full. Math.* **2** (50), 1, 19–26, 1958.

The two-dimensional steady-state form of Darcy's law is investigated for particular cases of nonhomogeneous permeability (k-) distributions. Two possibilities are considered: (1) $k^{1/2}$ is harmonic (satisfies the Laplace equation) and (2) $k^{1/2}$ satisfies the Helmholtz equation:

$$\Lambda k^{1/2} + \alpha^2 k^{1/2} = 0$$

It is shown that under these conditions Darcy's differential equation can be transformed into a Laplace or Helmholtz equation, respectively, by setting $\Phi = pk^{1/2}$ where p is pressure. The transformed equations can then be solved by means which are appropriate for Laplace and Helmholtz equations. The method is illustrated in two examples.

A. E. Scheidegger, Canada

5515. Semenov, G. A., The problem of the hydraulic resistance of a spherical column head (in Russian), *Sb. Trudi Povolzhsk. Lesotekhn. In-ta* no. 50, 137–150, 1956; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9007.

A criticism of results obtained by earlier investigators, in regard to the determination of the hydraulic resistance to the flow of a liquid or gas through a layer of discrete material particles enclosed between walls. In the author's opinion, the great disadvantage of all the formulas put forward in this regard is that they insufficiently consider all the conditions for geometrical similarity; consequently these formulas are particularly and not generally applicable, and only useful for the calculation of hydraulic losses in particular isolated cases. A description is given of author's experiments on the determination of the hydraulic resistance arising in the passage of an air flow through a distillation column head filled with spherical bodies, including details of the experimental method, the evaluation of the experimental data, and the results obtained. The equation for the resistance of a spherical head found by the author is, in generalized form,

$$\zeta = \left(\frac{A_1}{R_{cp}} + B_1\right)\left(\frac{D_k}{d}\right)^{0.065}$$

were R_m is the value of the Reynolds number calculated from the flow velocity referred to the cross-sectional area through which the air (fluid) passes, and according to the diameter d of the spherical head; D_k diameter of the column, A_1 and B_1 constants, wherein $A_1 = 7.5 \times 10^3$, $B_1 = 18$, for flow conditions corresponding to a Reynolds number $R < 365$, and $A_1 = 4.6 \times 10^3$, $B_1 = 26$ for $R > 365$. It is noted that the range of Reynolds numbers from 40 to 620 defines the transition region.

N. A. Zaks

Courtesy Referativnyi Zhurnal, USSR

5516. Mann, R. L., and Fatt, I., Effect of pore fluids on the elastic properties of sandstone, *Geophysics* **25,** 2, 433–444, Apr. 1960.

Bulk compressibility, Young's modulus, and Poisson's ratio were measured on three sandstones. Measurements were made on both dry and water saturated samples. Several runs were made on each sandstone to establish the statistical validity of the differences observed between the wet and dry samples. Bulk compressibility of wet sandstone was 10 to 30% greater than for dry. Young's modulus was 8 to 20% less for wet sandstone, and Poisson's ratio was 100% greater on one type of sandstone when wet and only slightly greater or about the same on wet samples of the others. A high clay content is believed to lead to a large effect of water on the elastic moduli of sandstone.

From authors' summary

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 5295, 5368, 5388, 5491, 5495, 5496, 5497)

5517. Olhovich, V.-A., Lateral velocity variations (in English and French), *Rev. Inst. Fr. Petrole et Ann. Comb. Liquid* **15,** 1, 112–120, Jan. 1960.

This is the problem of the construction of seismic rays. If the velocity of the propagation varies linearly not only with the depth z, but equally with the horizontal distance x, the problem can be reduced to the classical case through rotation of the axes Oxz.

An example of a chart is given for a particular case of velocity function

$$V = 2{,}000 + 0.25\,z + 0.50\,x \text{ cm/sec}$$

V. N. Baranov, France

5518. Turner, J. S., A comparison between buoyant vortex rings and vortex pairs, *J. Fluid Mech.* **7,** 3, 419–432, Mar. 1960.

Paper gives theoretical prediction of the diameter and velocity of vortex rings and vortex pairs as they rise through fluid with constant density gradient. Effect of initial circulation, momentum, and buoyancy are calculated. It is pointed out that bent-over plumes resulting from a point source of buoyancy in an ambient wind present an example of vortex pairs. Experimental evidence is presented supporting this.

Results indicate that lower initial buoyancy gives an increase in final height. It is suggested that waste gases could be propelled to greater heights by increasing initial circulation.

B. C. Watson, USA

5519. Zbrozek, J. K., and Pasquill, F., Note on conditions for which data on the power spectra of atmospheric turbulence are required, Aero. Res. Counc. Lond. Curr. Pap. 474, 5 pp., 1960.

5520. Charney, J. G., Hydrodynamics of the atmosphere and numerical weather prediction—a synthesis, *Proc. Nat. Acad. Sci., Wash.* **45,** 12, 1650–1655, Dec. 1959.

This brief paper represents a timely statement of the status of general atmospheric circulation theory. Comprehensive mathematical theory is not yet possible, but author states the essential problem and itemizes five principles upon which circulation theory now rests. Problem of general circulation is stated in hydrodynamical terms by author: "A distributed heat source decreasing in intensity from equator to pole produces a slow, axially-symmetric, convective circulation with a poleward temperature gradient and a zonal wind field increasing in westerly intensity with height. This flow is unstable for small-amplitude wavelike perturbations, which

therefore grow to finite amplitude and interact with the zonal velocity and temperature fields. It is required to calculate the mean properties of the final state of motion and ... the nature of the finite-amplitude perturbations." Author presents calculations of the first two unstable asymmetric modes of the simplified (two-level) mathematical model. Actual flow in the atmosphere appears to vacillate between these two modes, suggesting a shuttling of energy between these modes and mean flow.

K. H. Jehn, USA

5521. Priestley, C. H. B., Temperature fluctuations in the atmospheric boundary layer, *J. Fluid Mech.* **7,** 3, 375–384, Mar. 1960.

A systematic analysis is made of published measurements of the magnitude of temperature fluctuations in the atmospheric boundary layer. Within appropriate ranges of the variables, there is evidence for the existence of a dominantly forced convection régime, and also one wherein the predictions of the similarity theory of free convection are fairly closely approached. Subject to the limitations set by the recording systems used, regression relations are obtained for the magnitude of the fluctuations in terms of height and vertical temperature gradient or heat flux.

From author's summary by J. Laufer, USA

5522. Chiu, W.-C., and Greenfield, R. S., The relative importance of different heat-exchange processes in the lower stratosphere, *J. Meteorol.* **16,** 3, 271–280, June 1959.

Five years of radiosonde data taken 4 times daily by fifteen U.S. stations have been used to determine the mean diurnal temperature changes at heights corresponding to 50, 100, 150 and 200 millibars of pressure. Corrections are applied, and the residuals are attributed to the effect of radiation in heating and cooling the atmosphere. It is found that radiational temperature change in summer increases from $0.2^{\circ}C(12\ hr)^{-1}$ at 200 mb to $0.35^{\circ}C(12\ hr)^{-1}$ at 50 mb and that changes in winter are about 25% smaller. The mean absolute local temperature change was about $3^{\circ}C(12\ hr)^{-1}$ at 200 mb and decreased to about $1.5^{\circ}C(12\ hr)^{-1}$ at 50 mb. The horizontal advection of temperature was comparable to local change at 200 mb and decreased with height so that it was comparable to radiational temperature change at 50 mb.

R. G. Fleagle, USA

5523. Banilin, B. S., Mikhnevich, V. V., Repnev, A. I., and Shvidovskii, E. G., Problem on the measurement of pressure and density of high altitude atmospheric layers with the aid of artificial Earth satellites (in Russian), *Uspekhi Fiz. Nauk* **63,** 16, 205–225, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6496.

An investigation of the available models of the atmosphere shows that the pressure and density values accepted by different authors for altitudes of 200–500 km can be differentiated into two to three orders. Consequently the measurement of these magnitudes on a satellite, even if precise to within an order, would be of great importance for improvements in the theoretical models. At altitudes greater than 200 km, where the length of the free run of a molecule is greater than 10^3 cm, the interaction between the body moving at a great velocity and the atmosphere will take place in conformity with the principles of a free molecular flow. Expressions are examined for flows of the particles, impulse and energy in a free molecular flow. These principles enable linkages to be established between the pressure and the number of particles in the housing of the manometer located in the satellite and in the surrounding medium. In order to determine the density of the medium it is essential to know, in addition to the manometer readings, the speed of the satellite, the angle between the velocity and the normal to the section of the inlet orifice of the manometer, and the temperature of the gas in the manometer; for the determination of the pressure it is necessary to know in addition the temperature of the medium. As the formulas given in the paper refer to partial pressures and densities it is also essential to have information on the composition of the gaseous mixtures at the altitudes under investigation, which so far is only known very approximately.

It follows that apparatus which is able to measure density and the composition of the gaseous mixtures at these altitudes—namely, radiofrequency mass spectrometers and omegatrones—has a particular value. Use can also be made of ionization manometers on the satellite. The influence is investigated of some processes on the readings of the apparatus. The influence of impact ionization, impact dissociation and the elimination of atoms off the surface may, in the authors' views, be disregarded. Gas generation of the satellite, very noticeable initially, rapidly disappears. The electric charging of the satellite's surface might become an appreciable factor; in one of the missile experiments the potential of the missile at an altitude of 140 km reached 17v. The natural ionization of the atmosphere, reaching 10^6 ion/cm^3 may be the cause of error in the readings of ionization manometers; because of this a recommendation is made to insert ion traps at the inlet orifices of the manometers taking the form of condensers; the change in the number of particles because of the ions trapped is insignificant, as the concentration of charged particles is not more than 1% of the concentration of neutral particles.

Photo currents off the electrodes because of UV (ultra violet) radiation from the sun also could affect the manometer readings; consequently it is recommended to use electrodes protected against solar radiation, and, if this is not possible, to reduce their radiation surface. The manometers placed in the missile should be of small weight and volume, should possess a minimum period for stabilization, small sensitivity to temperature changes, small power requirements in regard to electric feed, a sufficient degree of stability to vibration and of insensitivity to overloads, stable calibration of curves by time, in a word it should be simple and reliable for autonomous service. A variant is described as regards constructional details of an ionization manometer and some technical points arising from its use are discussed. The measurement of density on the satellite was found to be just supplementary to the measurement of the density of the track of its trajectory.

M. N. Izakov

Courtesy Referativnyi Zhurnal, USSR

5524. Mikhnevich, V. V., and Khvostikov, I. A., A study of high altitude layers of the atmosphere (in Russian) *Izv. Akad. Nauk SSSR, Ser. Geofiz.* no. 11, 1393–1409, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6497.

This is a review of the work accomplished by Soviet scientists during forty years of Soviet rule. The basic methods used for investigating phenomena in the high altitude layers of the atmosphere are touched on briefly (direct and indirect methods; laboratory modelling, theoretical studies of the principles involved in atmospheric processes) as well as contemporary views on the structure and composition of the atmosphere. The main systematic features of the work done in the U.S.S.R. on determination by rocket of altitude to a fixed height and subsequent ejection are described. Detailed data are given for the meteorological rocket used. The measurements carried out in the U.S.S.R. show that the percentage of oxygen content shows no change up to an altitude of 95 km, but a tendency was observed of a drop in the argon content (per cent) at heights of 80–95 km. Data are given regarding temperatures and pressures up to altitudes of 80 to 108 km, measured in the Soviet by different methods. A comparison of the data obtained with the results of rocket investigations in the U.S.A. showed that at altitudes exceeding 80 km the values for the pressures recorded for measurements on the container and the meteorological rocket are smaller than measurements on rockets in the U.S.A. It seems possible that this difference is due to the influence of the gases separating from the rocket. For the temperature minimum at an altitude

of ~ 80 km the values obtained for the temperature showed very marked divergence and lay in the range of 150 to 220°K.

The paper concludes with a short survey of the fundamental results obtained when solving a number of theoretical problems dealing with the physical aspects of the high altitude layers of the atmosphere. From authors' summary

Courtesy Referativnyi Zhurnal, USSR

5525. Mirtov, B. A., Rocket investigations on the composition of the atmosphere at high altitudes (in Russian), *Uspekhi Fiz. Nauk* **63,** 16, 181–186, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6498.

Studies were carried out on the composition of the air at altitudes of 65 to 95 km by taking air samples in balloons sent up by rocket, the samples being analyzed in laboratories when received back on terra firma. The glass receptacles with a volume of 400 to 3000 cm^3 are placed in a container equipped with special safeguards in relation to the emission of gases. The container is ejected from the missile and returns to earth by the attached parachute. At a given height the valve of the receptacle opens automatically and closes ten seconds later, which represents the action of a vacuum stop cock lubricated by ozocerite. The samples were generally taken at the zenith of the trajectory at comparatively low velocities, 30–50 m/sec, which together with sufficiently large (1 cm^2) and short (not more than 1 cm) inlet openings should prevent the forced division of the gases when the gas is flowing into the inside of the receptacle and should ensure the rapid equalization of pressure inside and outside the receptacle. In view of the low pressures met with at the altitudes where the samples are collected, the quantity of gas in the sample when at normal atmospheric pressure is of the order of cubic millimeters or less. The analysis is carried out by the spectrum method by means of three calibrations. The accuracy of the analysis for oxygen and nitrogen is 5 to 6%, for argon 3%. The difficulties are discussed regarding the taking of samples, their preservation and analysis. The results obtained show that up to an altitude of 95 km there was no appreciable change in the correlation between the quantities of oxygen and nitrogen while the relative quantity of argon at altitudes of 85–95 km in the majority of samples was smaller than at the earth's surface. M. N. Izakov

Courtesy Referativnyi Zhurnal, USSR

5526. Burger, A. P., Scale consideration of planetary motions of the atmosphere, *Tellus* **10,** 2, 195–205, May 1958.

Naval Architecture and Marine Engineering

(See also Revs. 5025, 5097, 5270, 5303, 5319, 5460)

5527. Stefun, G. P., The influence of ship form on pitch and heave amplitudes, David W. Taylor Mod. Basin Rep. 1235, 22 pp., Sept. 1958.

Heave and pitch amplitudes are measured for five widely differing ship models tested in regular head seas. The motion results can be related empirically to a mean beam-draft ratio $c_\omega B/c_\nu H$ (heave) and the length displacement ratio $L/V^{1/3}$ (pitch). The experimental data obtained can be used to predict the amplitudes of similar hull forms. G. P. Weinblum, Germany

5528. Stefun, G. P., Model experiments with fixed bow antipitching fins, *J. Ship. Res.* **3,** 2, 14–23, Oct. 1959.

The results of experiments are communicated for a model of a naval vessel ($C_B = 0.61$) fitted with several alternate designs of *fixed* bow fins. A speed range $0 \leqslant F \leqslant 0.30$ and a wave-ship-length ratio $0.75 \leqslant 2/L \leqslant 1.5$ is covered. In general maximum pitch reductions are found for near synchronous conditions; they are appreciable even for a moderate ratio of fin plan area to waterline area ($\alpha = 0.02$). The increase of effectiveness is proportional to the increase of fin area for small α. High aspect ratios are favorable. The influence on the fin heave motion as well as on the resistance is more complicated.

G. P. Weinblum, Germany

5529. Christopher, K. W., and Johnson, V. E., Jr., Experimental investigation of aspect-ratio-1 supercavitating hydrofoils at speeds up to 185 feet per second, NASA TN D-187, 52 pp., Jan. 1960.

An experimental investigation has been made in the Langley high-speed hydrodynamics facility to determine the force and moment characteristics of two aspect-ratio-1 supercavitating hydrofoils (one having a flat bottom and one having camber) operating at zero cavitation number. Measurements were made of lift, drag, pitching moment, and spray location over a range of angles of attack from 3° to 20° for depths varying from 0 to approximately 1 chord. Tests were also made with the flat-bottomed hydrofoil at finite cavitation numbers to extend the range of data down to a cavitation number of 0.07. The range of speeds for the investigation was from 60 to 185 feet per second.

The results of the zero-cavitation-number tests are in good agreement with theoretical values of forces and moments. Experimental values of spray location are not in agreement with theory at high angles of attack but the agreement improves with decreasing angle of attack and the theory gives a good indication of the minimum angle of attack for which the two hydrofoils can be operated with a cavity from the leading edge.

From authors' summary by D. Savitsky, USA

5530. Buller, K., The hydrofoil boat, David W. Taylor Model Basin Transl. 293, 5 pp., Dec. 1959. [*Hansa*, no. 33/34 (1952), p. 1090, translated by E. N. Labouvie.]

This report gives a short summary of the development of the hydrofoil boat during the past 50 years. The limitations of size, the power required, and the stability of these high-speed boats are discussed. From author's summary

5531. Geurst, J. A., and Verbrugh, P. J., A note on camber effects of a partially cavitated hydrofoil, *Inter. Shipbldg. Prog.* **6,** 61, 409–414, Sept. 1959.

In an earlier publication: "Linearized theory for partially cavitated hydrofoils" [see following review] Geurst has presented a linearized theory applying to profiles with any arbitrary camber. By means of this theory Geurst has calculated the cavitated flow about *thin plates.*

In this publication the authors investigate the cavitated flow about slender-shaped profiles with a *slight camber,* it being assumed that the profile is of parabolic shape. The numerical calculation is made for the mean line of the profile which has been investigated experimentally by M. C. Meyer [see M. C. Meyer: "Some experiments on partly cavitating hydrofoils," *Inter. Shipbldg. Progr.* **6,** no. 60, 1959]. The results of present calculation (length of the cavitation cavity, lift, resistance, thrust) have been compiled in graphs and compared with Meyer's test results. The comparison shows that the profile lift forces as calculated according to the linearized theory are in fair agreement with the measured values, provided that the profile is sufficiently thin and that the angle of incidence is comparatively small.

However, the linearized theory breaks down when the length of the cavitation cavity on the suction side of the profile differs only slightly from the length of the profile.

M. Strscheletzky, Germany

5532. Geurst, J. A., Linearized theory for partially cavitated hydrofoils, *Inter. Shipbldg. Prog.* **6,** 60, 369–384, Aug. 1959.

Author investigates the steady-state cavitation on the suction side of a slender hydrofoil at a small angle of incidence.

It is assumed that the local velocity is the same over the whole surface of the cavitation cavity (q_c = const) and that the curvature of the mean line of the profile [$y = f(x)$] satisfies the condition $(df/dx) \ll 1$.

The calculation is referred to the chord of the profile (z-plane), and it is considered that the cavitation cavity forms a closed area. The boundary-value problem is solved by means of conformal mapping (ζ-plane). Subsequently, the behavior of the flow is studied at the stagnation points on the leading edge of the profile and in the neighborhood of the rear end of the cavitation cavity.

The method has been illustrated by a numerical example (flow about a plate).

The linearized theory proves unsatisfactory when the cavitation cavity covers almost the entire suction side of the plate.

Remarks of the reviewer: The author assumes the cavitation cavity to be a region of stagnant fluid. Although this assumption does not conform to reality, it can be made in the case under consideration. For more particulars on this subject reference is made to the publication (in German): M. Strscheletzky, "The hydro-dynamic equilibrium of flows of incompressible fluids," Internal Report no. 4436 of the Maschinenfabrik J. M. Voith G.m.b.H., Heidenheim/Brenz (1959). M. Strscheletzky, Germany

5533. Van Manen, J. D., and Wereldsma, R., Dynamic measurements on propeller models, *Inter. Shipbldg. Prog.* **6,** 63, 473–481, Nov. 1959.

Article presents a description and analysis of a dynamometer for measuring the thrust and torque of ship-propeller models under dynamic conditions. Design properties of the system (such as natural frequency, damping coefficients, etc.) are discussed, and the electronic test instrumentation is described in detail. Sample vibration and propeller performance records, obtained on four- and five-bladed propellers are presented and analyzed. A sampling technique provides good reproducibility of the periodic data.

A. Gessow, USA

5534. Breslin, J. P., and Tsakonas, S., Marine propeller pressure field due to loading and thickness effects, Soc. Nav. Arch. Mar. Engrs. Ann. Meet., New York, N. Y., Nov. 1959; Adv. Pap. no. 6, 32 pp.

Previous work on the calculation of the blade-frequency pressure field about a ship propeller (in the absence of a hull) has been incomplete in that only the field due to thrust and torque loading was considered. This paper deals with the total field produced by blade-thickness effects as well as that due to loading. This new treatment has produced closed-form answers in terms of tabulated elliptic integrals to replace the numerical harmonic analysis formerly employed. Asymptotic formulas of extreme simplicity are presented to reveal the dependence of the pressure on the major parameters such as tip clearance and number of blades. Comparison with experimental results for one model of a ship propeller shows that this complete theory now explains the observed axial-pressure signature and gives very satisfactory agreement with the data obtained over a range of tip clearances. The simple asymptotic formulas are found to give surprisingly good interpolation of this variation with radial distance from the propeller, and may be used tentatively for estimates of the changes to be expected in this vibration-exciting pressure field (over a practical range of tip clearances) as the number of blades, thrust, blade thickness, and so on, are varied. The material in the body of the paper is presented in physical terms which should appeal to the practicing naval architect; all mathematical developments are relegated to appendixes.

From authors' summary by M. S. Weinstein, USA

Friction, Lubrication and Wear

(See also Revs. 5039, 5132, 5294)

5535. Ott, H. H., Position of the shaft and friction in a triple-wedge bearing, *Broun Boveri Rev.* **46,** 7, 395–406, July 1959.

The triple-wedge bearing is analyzed by an approximate method. Position of shaft and friction are calculated for steady-state conditions. Maximum film pressures and forces in the three segments are also calculated. Lubricant viscosity is assumed constant and two-dimensional flow theory is employed.

Compared with the conventional journal bearing the triple-wedge design offers the advantages of (a) improved stability of the shaft at light loads, and (b) more nearly concentric operations over a wide load range.

Results are given in the form of generalized curves.

F. E. Macks, USA

5536. Ebihara, K., and Hayashi, K., An application of dimensional analysis to the characteristics of wear under dry condition, *Bull. JSME* **3,** 9, 6–12, Feb. 1960.

A dimensional analysis is made with the following variables included: Normal pressure, sliding speed, sliding distance and resistance to sliding (the latter a function of the mean temperature of the rubbing surfaces). It is shown that specific wear, wear per unit pressure per unit sliding distance, is a function of a three-nondimensional factor product. The primary nondimensional factor is a simple quotient of factors representing pressure, sliding speed, a characteristic length, surface temperature and the heat conductivity. The other two which turn out to be corrective factors are fractions involving specific heat, weight density, resistance, Reynolds number and some of the variables in the primary factor. There are favorable checks with experimental data and consistency with the Holm theory. M. G. Scherberg, USA

5537. Toyoguchi, M., and Takai, Y., Determination of load-carrying capacity of lubricating oil by I.A.E. type gear-lubricant testing machine, *Bull. JSME* **2,** 8, 545–550, Nov. 1959.

Effect of various E.P. additives on load-carrying capacity is determined in the I.A.E. gear machine, the Timken machine and the Soda four-ball machine. Results are compared.

W. J. Anderson, USA

5538. Szoke, B., The possibility of kinetic vibrations in antifriction bearings (in English), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 1/2, 3–24, 1959.

For antifriction bearings the presence of a clearance between the enveloping circle of the rolling elements and the outer raceway permits kinetic vibrations of the shaft center even with a balanced rotating mass and a bearing assumed as being perfectly rigid and of faultless shape. This vibration pattern consists of a pair of curves, one of which is an arc of circle and the other one is given by the tilting back of the ball cage.

For a given bearing and a given load the displacement angle of the starting point of vibration is function of the rotational speed. At constant speed invariably the same spot on the race is attained by the dynamic actions, and this may lead to scaling. There exists a speed at which the final phase of the vibration takes place exactly after completion of a rotation equal to one pitch of the rolling elements. For each antifriction bearing a factor can be computed which depends only on the design data of the bearing and which, multiplied with the square of the angular velocity of the cage, gives that external load per unit rotating mass at which the dynamic actions due to kinetic vibrations are the strongest. There exists also a *rotational limit speed* at which the vibration will cease and a circling motion will be performed by the shaft center.

It was tried to determine with the aid of the *Thales* circle, for a bearing of given design data, those operative conditions character-

ized by the pole distance $p = \frac{a}{\omega_k^2}$ under which various characteristic phenomena occur. From the computations it appears that a particular *Thales* circle belongs to each pole distance, determining the form of the vibration path.

From author's summary

5539. Panov, V. V., and Sobolev, Yu. S., Lubricating oils for aviation gas turbines, NASA TT F-21, 82 pp., May 1960.

The ultimate serviceability of gas turbine engine lubricating oils is assessed on the basis of results of tests on individual frictional assembly installations of engines and on full-scale engines. In certain cases, oils are tested under in-flight conditions.

From authors' summary

5540. Iida, K., and Igarashi, A., On the behaviour of rollers in a cylindrical roller bearing, *Bull. JSME* **2**, 8, 538-545, Nov. 1959.

Photographic techniques were used to experimentally study roller motion. A theoretical expression is developed which compares favorably with the results. In most cases the roller behavior agrees well with conventional theory. In cases of large radial clearance some deceleration of the roller was noted in the approach to the loaded zone. W. J. Anderson, USA

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